Rio Blanco Oil Shale Company

SCOPE OF WORK
MODULAR DEVELOPMENT PHASE
ENVIRONMENTAL MONITORING PROGRAM
TRACT C-a OIL SHALE LEASE

December 15, 1980

Gulf Oil Corporation / Standard Oil Company (Indiana)
'A General Partnership'
2851 South Parker Road, Aurora, Colorado 80014

Revision 6.0
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SCOPE OF WORK

RBOSC Modular Development Phase
Environmental Monitoring Program

Tract C-a Oil Shale Lease

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and
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SCOPE OF WORK

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Quality assurance should also be presented for Sections 2.0 (air)
3.0 (meteorology)
4.0 (terrestrial)
5.0 (aquatic)

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1.0 INTRODUCTION

Rio Blanco Oil Shale Company (RBOSC) has been conducting environmental monitoring studies on Tract C-a since the completion of baseline and interim period inventory studies on September 30, 1977. The monitoring studies have been conducted to assess the impact of oil shale operations on Tract C-a and the vicinity as development progresses. Prior to October 13, 1980 (the date of ignition of the first MIS retort), however, the development was confined to surface disturbances in a relatively small area (<400 acres) related to construction activities, and dewatering and reinjection. Therefore the data collected between October 1, 1977 and October 13, 1980 are largely indicative of baseline conditions.

Monitoring studies have been conducted in accordance with the program described in the RBOSC Modular Development Phase Environmental Monitoring Program dated May 1977 and approved by the ~~Area Oil Shale Supervisor~~ Deputy Conservation Manager -Oil Shale (DCM/OS) on August 17, 1977.

An amended version of this program (Revision 5.2) dated March 30, 1979 was approved by the ~~Area Oil Shale Supervisor~~ DCM/OS on April 16, 1979 with 17 conditions. The monitoring program currently being conducted complies with Revision 5.2 and the 17 Conditions of Approval.

Revision 5.2 covered the period from January 1979 through December 1981. However, RBOSC has now modified their development plans and will begin construction of a surface retort, open pit mine, and associated ancillary facilities and corridors in the spring of 1981. In order to monitor potential impacts of these operations, RBOSC has revised the monitoring program again. This program (Revision 6.0) is described in this document. RBOSC will modify sampling activities in accordance with Revision 6.0 after approval by the ~~Mining Supervisor~~ DCM/OS.

By mutual agreement, this monitoring program is reviewed quarterly by the ~~Area~~ Oil Shale Office (OSO) staff and modified as necessary to ensure adequate coverage of all potential impacts. Modifications which are approved during the calendar year are implemented as soon as feasible after approval. A record of all modifications is kept in a master volume in RBOSC's offices and in the RBOSC Quality Assurance File. If modifications to the program are substantial, a revised document bearing a new revision number (e.g. 6.1) will be published.

1.1 OBJECTIVES

The Tract C-a lease stipulates that a monitoring program shall be conducted before and during development operations, to provide 1) a record of changes from pre-development environmental conditions; 2) an ongoing check of compliance with lease provisions and applicable Federal, State, and local environmental control requirements; 3) timely recognition and notice of any adverse impacts; and 4) a factual basis for revision of lease stipulations. The monitoring program is designed to meet these stipulations as well as to satisfy the specific monitoring requirements requested by the ~~Area~~ Oil Shale Office (~~A~~OSO).

The environmental monitoring program is also designed to provide an indication of how successful, in fact, the planned mitigation measures prove to be. To test the success of planned mitigation measures, RBOSC will monitor the type, severity, and duration of impacts which result from the MIS operations and the proposed Lurgi Demonstration Project. The results of this monitoring will be the principal means of evaluating the adequacy of planned mitigation measures.

Will impacts be separated as to MIS or Lurgi sources, or will all impacts be cumulative? Should be some mention of RBOSC objective.

Introduce control / treatment concept.

1.2 MONITORING PROGRAM DEVELOPMENT

Development of an environmental monitoring program is a dynamic process involving identification of potential impacts, selection of methods to monitor these impacts, compilation and analysis of data, and feedback.

Requisite to the measurement of development-related impact is a thorough knowledge of pre-development, baseline environmental conditions. For Tract C-a this knowledge was obtained through a two-year baseline study. The results of this study are summarized in the Final Environmental Baseline Report (RBOSP 1977a).

Environmental impacts to be monitored as a part of this program have been selected on the basis of their significance, measurability, and indicator value. This process was thoroughly described in the Final Environmental Baseline Report and Progress Report 10 (RBOSP 1977b). RBOSC environmental specialists have evaluated the measurability of those impacts which were assessed as significant, and have developed programs to monitor these impacts.

Impacts which were assessed as significant, measurable, and having dependable indicator parameters were selected for monitoring. Some exceptions were made for impacts which are sensitive from a public or regulatory standpoint, and for specific monitoring requirements of the ~~A~~OSO. The selected impacts are believed to reflect environmental conditions on Tract C-a and the adjoining project area. Data obtained from the monitoring program will be analyzed and fed back into a re-assessment process to confirm that the objectives of the program are being accomplished. If not, the program will be modified as necessary, in consultation with the ~~A~~OSO. Monitoring methods selected by RBOSC environmental specialists are based on their personal experience, on data collected during the baseline studies, and on knowledge of the type and format of data required by various agencies.

also based on the environmental assessment matrix

Treatment sites were also based upon results of air quality modeling.

1.3 MONITORING PROGRAMS

Monitoring and/or evaluation programs have been developed for the following environmental components:

- 2.0 Air Quality
- 3.0 Meteorology
- 4.0 Terrestrial Ecology
- 5.0 Aquatic Ecology
- 6.0 Hydrology
- 7.0 Special Studies
- 8.0 Ecological Interrelationships

This scope of work supplies detailed information on specific objectives and the development of techniques designed to accomplish these objectives. In most cases, objectives involve determining whether certain project-related activities are significant sources of impact on the environmental component in question.

RBOSC has established quality assurance, data management, and reporting procedures as part of the environmental monitoring program. These procedures are described in each section. An overall description is given in Section 9.0, Quality Assurance, Data Management, and Reporting Procedures.

LITERATURE CITED

Rio Blanco Oil Shale Project. 1977a. The Final Environmental Baseline Report. Gulf-Standard, Denver, Colorado.

Rio Blanco Oil Shale Project. 1977b. Progress Report 10. Gulf-Standard, Denver, Colorado.

2.0 AIR QUALITY STUDIES

Development of the tract may result in various disturbances to the air environment. An intensive effort to quantify any disturbance has been made since RBOSC obtained the lease to Tract C-a. The ambient air quality of the area was measured very intensively before development during the baseline studies (at four sites), on a reduced scale during the interim period (at one site), and is again being measured intensively at three sites as tract development progresses.

The baseline studies showed that, on the average, measurable values of CO, NO, NO_x, H_2S and SO_2 were not present on the tract. Measurable quantities of methane (CH_4), total hydrocarbons (THC), ozone and total suspended particulates were detected on the tract. The average methane concentration was near the global average. Although federal guidelines exist for nonmethane hydrocarbons (NMHC, obtained by subtraction of methane from total hydrocarbons), NMHC concentrations measured were often unreliable due to the inherent errors in the available monitoring techniques. Although the site is located in a pristine area, ozone was often detected during the baseline studies at concentrations approaching the National Ambient Air Quality Standards (NAAQS). In 1978 the NAAQS for ozone was raised by 50%, however, which has alleviated this problem. The average particulate concentrations measured during the baseline were fairly low, which is characteristic of a semi-arid region in a remote area. In general, the four baseline stations provided one set of background air quality data and three additional data sets that provided support information.

Since only hydrocarbons and ozone of the gaseous constituents were found in measurable quantities during the baseline studies, most interpretative discussions of air quality in the area have centered around these pollutants. The hydrocarbons are important primarily because they are precursors to photochemical smog. Over 90 percent of the average measured baseline hydrocarbon concentration was methane, the least reactive hydrocarbon. The source of the nonmethane hydrocarbons could not be definitely identified, however; possible sources were ,,.......,

Relatively high ozone concentrations, such as found on the tract, are typical of many rural or remote locations. The cause of these elevated ozone concentrations is still subject to debate, and may be due to natural reactions occurring at the site, stratospheric injection, long range transport or some combination of these processes.

An air quality dispersion modeling study has now been completed to determine areas of maximum concentration of certain pollutants emitted from the combined operations of the modified-in-situ and Lurgi surface retorts and to provide an estimate of these concentrations. The pollutants modeled include SO_2, NO_2 and particulates. Both a short-term and a long-term model were used to evaluate the expected impacts during various time periods. In summary, the study showed that applicable air pollution standards will not be violated, and the highest concentrations are expected to occur to the west of the tract (although on relatively rare occasions). This maximum impact results from the rise in terrain to the west but may be largely an artifact due to the assumptions inherent in the model.

should be discussed in general monitoring introduction

A matrix analysis was completed during the MIS assessment to estimate potential development impacts on the biotic and abiotic components of the ecosystem at the tract. A similar procedure has been used to assess combined impacts of Lurgi and MIS development. Particulate concentrations in the vicinity of the tract are expected to be affected to a slightly or moderately important degree by construction activity, ore blasting and storage and spent shale disposal. Gaseous concentrations in the vicinity of the tract are expected to be affected to a slightly or moderately important degree by surface and underground retorting, motorized vehicles and the increased manpower on the site.

OSO needs copy of revised environmental assessment matrix!

2.1 AMBIENT MONITORING

A. Gaseous Constituents

1. Objectives

With the increased activity on the tract as development proceeds, certain changes may occur in the ambient air quality due to the construction of the facilities and by the processing of the oil shale. The purpose of the air quality monitoring program is, therefore, to provide a quantitative basis for evaluating any changes in the ambient constituents. Specific objectives are:

- To measure the ambient levels of specific air quality parameters and determine long-term trends in the air quality around the tract.
- To provide air quality data which can be compared to the relevant state and federal air quality standards.
- To provide air quality data which allows the implementation of a control/treatment concept in assisting in the evaluation of tract influences on the ambient air quality.
- To provide a continuous time series of air quality data, which will allow, in conjunction with the meteorological data, analysis of the air quality impact of emissions on the tract.
- To provide data which will allow validation and perhaps improvement of the air quality models which have been used to predict the air quality impacts resulting from tract emissions.

The air quality data and technical interpretation will also be available for studies by other disciplines of cause/effect relationships, e.g., changes in the growth rate of flora or the pH of local streams.

2. Methods

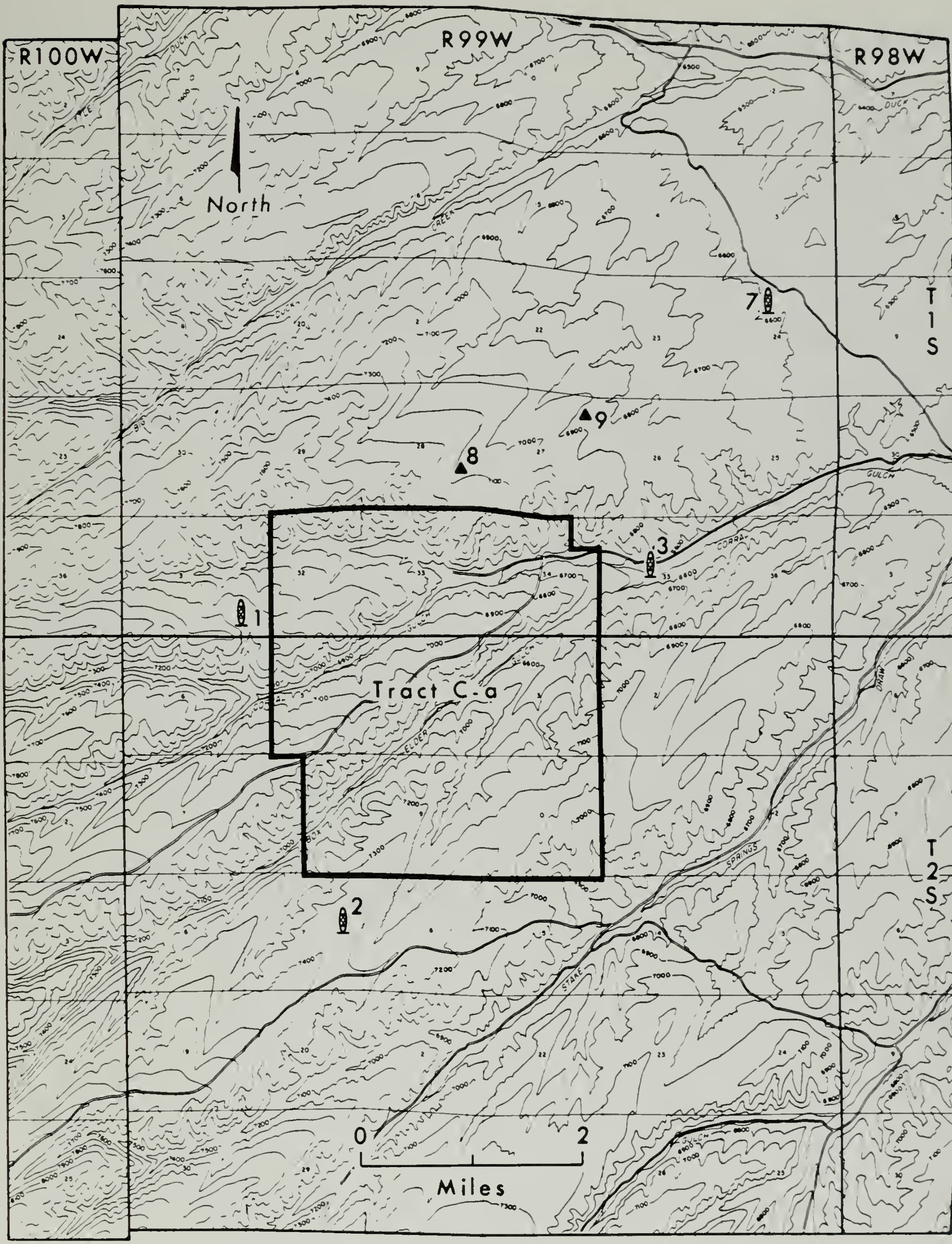
Certain air quality gaseous constituents are monitored continually with automated instrumentation. The pollutants being measured were chosen because either tract operations are expected to release these pollutants or because they are necessary to characterize the air quality of the region, or as required by law. The data are recorded with an automatic digital data acquisition system backed up with strip chart recorders. The instruments are housed in strategically located, environmentally controlled shelters. RBOSC is currently planning to upgrade the automatic acquisition system with the latest state-of-the-art equipment. This data acquisition system will scan each parameter 12 times each minute and computes an interim five-minute average. The average values will be recorded on magnetic tape at the end of each hour. Hourly averages are computed from the interim averages.

a. Parameters - The air quality parameters monitored in the vicinity of the tract are SO_2, H_2S, CO, NO, NO_x and O_3. Total hydrocarbons and CH_4 were measured at Site 1 until February 1978, when they were discontinued with the approval of the AOSO, due to the inaccuracy of the NMHC calculation.

b. Monitoring Locations and Schedule - Figure 2-1 illustrates the monitoring locations currently active or planned around the tract. Table 2-1 lists the baseline monitoring schedule, and Table 2-2 lists the current or planned monitoring schedule. Site 1, just west of the tract boundary, is the location at which the greatest number of air quality and meteorological parameters have been monitored to date. Continued monitoring at this location will provide continuity with the baseline data set so that natural changes in the ambient air quality may be detected. In addition to the data set continuity, Site 1 provides a valuable measurement of the ambient air quality of the region (the control site) due to its location, which is upwind of the tract development.

contradictory

The air quality modeling results indicate, as discussed earlier, that the largest impact from the combined Lurgi and MIS processes will be to the west of the tract, near Site 1. It is quite likely that these impacts will not be observable, both because of the inherent uncertainties in the model and the



Meteorological & Air Quality Monitoring Sites

▲ Hi-Vol Monitoring Sites

off-tract property

Figure 2-1

Meteorological & Air Quality Monitoring Sites

Table 2-1. Baseline Air Quality Monitoring Schedule

Parameter	Location	Monitored Dates	Frequency
Sulfur Dioxide (SO_2)	Sites 1,2,3,4	Feb. 1975 - Jan. 1977	Continuous
Hydrogen Sulfide (H_2S)	Sites 1,2,3,4	Feb. 1975 - Jan. 1977	Continous
Nitric Oxide (NO)	Sites 1,3	Feb.1975 - Jan. 1977	Continuous
Nitrogen Oxides (NO_x)	Sites 1,3	Feb. 1975 - Jan. 1977	Continuous
Carbon Monoxide (CO)	Sites 1,3	Feb. 1975 - Jan. 1977	Continuous
Ozone (O_3)	Sites 1,3	Feb. 1975 - Jan. 1977	Continuous
Methane (CH_4)	Sites 1,2,3,4	Feb. 1975 - Jan. 1977	Continuous
Total Hydrocarbons (THC)	Sites 1,2,3,4	Feb. 1975 - Jan. 1977	Continuous
Particulates (TSP)	Sites 1,2,3,4	Feb. 1975 - Jan. 1977	Every 3rd Day

Note: Site 4 was located about 5 miles downvalley from Site 3 and has since been deactivated

Table 2-2. Current Air Quality Monitoring Schedule

Parameter	Location	Monitored Dates	Frequency
Sulfur Dioxide	Site 1	Sept. 1977	Continuous
	Site 3	Jan. 1978	Continuous
	Site 7	Fall 1982	Continuous
Hydrogen Sulfide	Site 1	Sept. 1977	Continuous
	Site 3	Jan. 1978	Continuous
	Site 7	Fall 1982	Continuous
Nitric Oxide	Site 1	Sept. 1977	Continuous
	Site 3	Feb. 1980	Continuous
	Site 7	Fall 1982	Continuous
Nitrogen Oxides	Site 1	Sept. 1977	Continuous
	Site 3	Feb. 1980	Continuous
	Site 7	Fall 1982	Continuous
Carbon Monoxide	Site 1	Sept. 1977	Continuous
	Site 3	Jun. 1980	Continuous
	Site 7	Fall 1982	Continuous
Ozone	Site 1	Sept. 1977	Continuous
	Site 3	Nov. 1979	Continuous
	Site 7	Fall 1982	Continuous
Particulates	Sites 1,2,3	Dec. 1977	Every 3rd Day
	Sites 7,8,9	Summer 1981	Every 3rd Day

very low level of predicted impacts. Thus, Site 1 will serve two functions: 1) it will be upwind of the tract activities during normal wind patterns, thereby acting as the control site and 2) occasionally (during unusual wind patterns) it will be downwind of the tract activities, and will provide an opportunity to validate the model. These two functions can be separated out by reference to the wind direction data simultaneously collected at Site 1.

Site 3, also operational during the baseline period, is located in the approximate center of the drainage valley leading away from the northeast corner of the tract. Any air quality impacts from the MIS operations should be evident first at Site 3 (the treatment site) for two reasons: the prevailing westerly winds will carry the tract emissions over Site 3, and nighttime drainage winds from the tract development area may tend to carry the low-level emissions down into this valley where they will be trapped during the frequent nocturnal inversions. Air quality measurements at Site 3 were discontinued after the baseline period, but have now been fully reactivated (Table 2-1).

Site 7 is shown on Figure 2-1 located to the northeast of the Lurgi surface retort. The justification for locating an air quality and meteorological monitoring site at that point is analogous to the reasoning used in locating Site 3 in Corral Gulch, downvalley from the MIS process area. Because the Lurgi retorting emissions will be transported toward Site 7 much of the time, both by the prevailing winds and by the downslope drainage flow, this station may measure higher concentrations of pollutants than the other monitoring sites. Higher concentrations at Site 7 were not predicted by dispersion modelling, but current state-of-the-art models are incapable of adequately treating flow into valleys. Thus, this station will provide an additional opportunity to evaluate both the accuracy and the adequacy of the models.

The precise location of Site 7 has not yet been determined, and will depend upon three factors: 1) evaluation of the air quality modeling results for the Lurgi demonstration project , 2) a detailed review of the topographic maps and a site survey (in cooperation with the AOSO) and 3) the results of special studies, such as the DOE Yellow Creek Meteorological Study or similar intensive short term studies around the tract (planned for the future).

As noted in Table 2-1, Site 7 will not be operational until the Fall of 1982, approximately two to four months before the startup of the Lurgi surface retort. Since the background air quality has been extensively documented, there is no reason for operating this new air quality site until shortly before startup of Lurgi retort (to allow time for the site to become fully operational).

Need sufficient time t
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collect some
"baseline" dat

RBOSC plans to take advantage of possible non-overlapping schedules of the burning of the MIS retorts and the startup of the Lurgi surface retort. That is, the monitors for the gaseous constituents will be moved from Site 3 to Site 7 after the last MIS burn and before the startup of the Lurgi retort. If a change in the operation schedules indicates that the burning schedule of the two retort types will overlap, additional air quality monitors will be purchased and installed at Site 7 so that it will be operational before startup of the Lurgi retort.

The locations of the air quality monitoring systems at Sites 1, 2 and 3 will be periodically reviewed during development to ensure that these sites are representative of the conditions they were designed to measure. If a review indicates that relocation of one of the sites is desirable, such a change will be incorporated into the monitoring system with the concurrence of the ~~A~~OSO. The selection of the new site will be based on previously conducted tracer tests, air quality modeling, relevant special studies and the latest monitoring data.

c. Monitoring frequency - The onsite instrumentation presently being used for measurement of the gaseous air quality constituents is capable of continuous operation when supplied with reliable commercial power.

When the instruments are serviced and maintained on a regular schedule, data recovery is expected to be near 90 percent on an annual basis. This recovery rate exceeds the Federally recommended minimum of 75 percent (EPA 1976). An upgraded automatic data acquisition system is to be installed at each site. This new system will continue to record both meteorological and air quality data, like the current system, but should reduce the maintenance problems and

improve data recovery. This system automatically scans all parameters 12 times each minute and computes fifteen-minute and 1-hour averages of the meteorological and air quality parameters. These data are stored on magnetic tape. All time designations are in local standard time (Mountain Standard) and the seasons of the year are defined as: Spring - March, April and May; Summer - June, July and August; Fall - September, October and November; and Winter - December, January and February. Data hours are computed from data acquired during the hour. For instance, the 0200 data point is the data average from 0130 to 0230 hours. The fifteen-minute data averages are not ordinarily utilized, but are recorded and are available for future study, if necessary.

d. Instrumentation and data acquisition techniques - The air quality monitoring instruments used at the tract meet the standards of the Federal reference methods. Instrumentation is replaced if it gives unsatisfactory performance due to age or general wear. The monitoring system will be upgraded as necessary with state-of-the-art instrumentation if significant advances are made in instrument technology and in response to regulatory requirements.

Two parallel methods are used for data acquisition from the air quality monitoring instruments. In the primary system, the instrument output signal is digitized electronically, averaged by a computer and recorded on both magnetic tapes and paper hard copy. In the backup system, the instrument output signal is recorded on a channel of a multipoint strip chart recorder.

e. Data handling and quality assurance procedures - Magnetic tapes and strip chart records are transferred from the site to the Denver headquarters by courier every two weeks. The tapes are logged in by a programmer, the data dumped in easily readable format, reviewed by an analyst and filed for quarterly batch processing. The strip charts are logged in by a technician and reviewed by an analyst when data are not available from disk or the onsite hard copy. If insufficient data are recovered from the magnetic tape record, data reduction technicians supplement the data set by reducing additional data from the strip charts. Documented work instructions for defining missing data, determining hourly averages, minimum detectable level, etc., are used for manual data

reduction. Manually reduced data are punched on cards and merged with the magnetic tape data. The digital system is checked on a one-hour-per-week basis by comparing the digital values of all parameters with the analog values derived from the strip charts for the same time period.

Operation and maintenance of the air quality instrumentation are performed by site technicians. A station log is maintained in which relevant information is recorded each time the facility is visited. In addition, the technician has a site-specific checklist on which to record instrument performance tests, and a documented work instruction for site surveillance. These records are completed at least once each week. Performance tests require a zero and span check of all instruments. These tests consist of switching the instrument sample line from the ambient air intake manifold to a known gas concentration obtained either from a standard gas cylinder or a permeation tube source that has been standardized. Quality control charts are maintained to record the results of the zero and span tests. Control limits as recommended by EPA quality assurance procedures are established to maintain acceptable instrument performance.

Calibration of the air quality instrumentation is performed at least once each 90-day period. These calibrations, along with the control charts, are used to evaluate instrument accuracy. The calibrations are performed in accordance with documented work instructions by using either permeation tubes or gas cylinders traceable to NBS, per EPA protocol recommendations.

Scale factors for each parameter are established from the nominal span settings of the instruments. Corrections to these scale factors are developed from the internal quarterly calibrations, if analysis of the calibration results show that corrections are necessary.

The final scale factors are applied to the air quality data, which are assembled into a complete and finished data set on a six-month basis. This data set is then combined with the meteorological data and written on a magnetic tape with a SAROAD header file.

been discontin

The site technician also cooperates with the EPA-sponsored program "Quality Assurance in Support of Energy Related Monitoring Activities in the Western United States," which provides a quarterly round-robin calibration backup check using independent test gases and instrumentation. Quarterly dynamic gas calibrations are performed with test gases which are independent of the gas reference cylinders maintained on site for the weekly dynamic tests.

Additional quality assurance will be provided through semi-annual internal audits. These include site visits, and are designed to insure that both site personnel and technical office personnel are following prescribed procedures as given in this work scope, the work instructions and applicable sections of the RBOSC Quality Assurance manual.

3. Experimental Design and Data Analysis

The objective of the air quality monitoring program is to document quantitatively any substantial changes in the air quality around the tract. There are two methods by which this can be done: the baseline data can be used as a control and tested against data during the development period for those monitoring sites that have been active during both periods; or the background monitoring site (Site 1) can be used as a control and tested against the monitoring site which is expected to be affected by tract operations (Site 3 or Site 7).

The following hypotheses will be tested:

H_0: There is no significant difference in the concentrations of gaseous pollutants measured during the baseline period and the development phase at each monitoring station.

H_0: There is no significant difference in the concentrations of gaseous pollutants monitored among any of the RBOSC air studies sampling sites.

Because the air quality monitoring is performed on a continuous basis, the sample sizes will be very large. When possible, each monitored pollutant will

be tested according to the hypotheses given above, by using techniques such as analysis of variance and multiple regression. However, it is difficult to specify exact statistical techniques that will be used in the analysis of the air quality data before preliminary review, since the magnitude of any observable air quality impacts due to tract development cannot be accurately predicted at this time. These techniques will be selected after review of suggested analyses described in the literature and EPA publications, and after consultation with the AOSO.

The major purpose of the air quality data analysis will be to gain a better understanding of the pollutant sources and sinks and the dynamic interactions affecting pollutant concentrations on the tract. The onsite meteorological data will be used extensively to aid in the air quality analysis.

A high degree of flexibility will be maintained in the analysis program so that unexpected or interesting results can be studied in detail when such a course of action appears to be warranted. For instance, an increase in measured SO_2 concentrations on the tract during a retort burn may occur and will be watched very carefully. Changes to the permanent monitoring system and the analysis procedure will be considered, based upon the results from the initial retort burns. Comparisons will be made between monitored results at each site and the federal and state regulatory standards.

Close liaison will be maintained between the air studies team and the biological and hydrological teams involved in monitoring programs on and near the tract. Guidance in determining the areas of maximum pollutant concentrations and probable maximum environmental impact will be based upon modeling results and current air quality data, so that their monitoring programs can be designed and adjusted to best measure possible effects due to the changes in the tract environment. In this manner, both acute and chronic effects on the biotic and abiotic factors can be properly measured and analyzed.

B. Particulates

1. Objectives

Suspended particulate matter is of concern on and near the tract because it is subject to Federal and state regulations. It is, therefore, extensively monitored in the environmental program. Specific objectives are as follows:

- To provide data which can be compared to the relevant federal and state ambient air quality standards.

- To provide a data set during tract development which can be compared with the baseline data set.

- To attempt to correlate measured particulate loadings with specific sources and with other significant air quality and meteorological parameters.

The concentration of suspended particulate matter on the tract was shown to be low during the baseline studies. A general trend occurs in the data set of very low ambient particulate concentrations during the winter months (due primarily to the snow cover), and higher concentrations during the warm, dry summer.

This background particulate matter will be augmented by four types of sources during development. The first two source types are the increased traffic on the network of dirt roads around the tract and the construction activity at the processing sites. After the initial construction phase is completed, the contribution due to construction activity should decrease. The third source of particulates will be from shale ore production, crushing, processing, overburden and disposal. The fourth source will be ~~spent~~ processed shale disposal piles. As can be readily seen, the number and types of particulate sources and the concentration of suspended particulate matter will change with time during tract development. The potential particulate problems will be carefully studied and analyzed, in consultation with AOSO and EPA. RBOSC is currently

Will program be able to determine the specific source of particulates instead of general tract development.

conducting a series of research programs devoted to the resolution of this issue. We anticipate continuing these activities throughout the Lurgi demonstration project. RBOSC will cooperate with the EPA and other organizations in providing filters for analysis of particle size and composition as a part of the EPA's proposed visibility program.

2. Methods

which will be used?

a. Parameters - Total suspended particulates ~~are~~ measured according to the Federal reference method using high volume samplers. In addition, particle size will be determined by using specialized sampling techniques such as cascade impactors, size-selective inlets or dichotomous samplers. Final selection of appropriate samplers will be made after consultation with EPA and the AOSO. Decide now.

b. Monitoring Locations and Schedule - High volume samplers are operated at Sites 1, 2, 3, 7, 8 and 9, (Figure 2-1) and are located approximately 5 m above ground elevation. Sites 1 and 2 are located generally upwind of the tract development and therefore serve as control sites. Site 3 is located generally downwind and in a gulch that drains the MIS development area. Sites 7, 8 and 9 are located downwind of the Lurgi site, the run-of-mine ore disposal site and the spent shale disposal site, respectively. As a result, they will serve as treatment sites. Sites 7, 8 and 9 will primarily monitor construction activity around the Lurgi retort at first, but will measure emissions from the Lurgi retort and the storage and disposal piles after retort startup. Progress of the operations will be carefully documented and discussed in the year-end reports as a means of relating the potential impact to its source. Although the installation of new air quality monitoring sites will not be completed until 1982, the Hi-Vol monitors will be installed around the Lurgi site as soon as the Summer of 1981. Should be installed prior to site construction.

The suitability of the monitoring locations will be subject to periodic review based on analysis of the data. If it appears that additional samplers or relocation of existing samplers is necessary, appropriate modifications will be worked out in consultation with the AOSO.

c. <u>Monitoring Frequency</u> - At least three Hi-Vol monitors have been in operation since the start of tract development (Tables 2-1 and 2-2). A 24-hour high-volume sample is taken at each of the three sites every third day. Such data will be taken at six sites starting in the summer of 1981. A day is defined as 0000 hours to 2400 hours.

d. <u>Data Acquisition Techniques and Instrumentation</u> - General Metal Works high volume samplers with Sierra flow controllers are used to acquire samples. An electric clock timer controls the on-off cycle of the sampler. Unexposed filters are conditioned and weighed at the air quality laboratory using the EPA reference technique. The balance is standardized with class S weights. Filters are coded and supplied to the field ready for use. Exposed filters are cycled through the same analytical procedure upon their return to the air quality laboratory.

e. <u>Data Handling and Quality Assurance Procedures</u> - The high volume sampler flow rates are calibrated quarterly with a standard orifice plate to determine the flow rates to be used to calculate particulate concentration. The standard orifice plate is calibrated annually at EPA's Region VIII laboratory in Denver.

Each exposed filter carries with it a location verifier and flow meter readings taken before and after sampling by the field technician. Weight determinations are maintained in a log in the air quality laboratory and filters are stored for future reference if chemical composition or radioactivity levels are required. In accordance with EPA protocol, a minimum of 10 percent of the filters are reconditioned and reweighed as a quality assurance check.

The field technician cooperates with the EPA Western Energy Quality Assurance Program in the parallel calibration of sampler flow rates.

The particulate data are stored on magnetic tapes on a semi-annual basis for future reference.

3. Experimental Design and Data Analysis Procedures

The purpose of the monitoring program is to define and quantify changes in the total suspended particulate matter around the tract as a result of tract development. To that end, the following hypotheses will be tested:

> H_o: There is no significant difference in the concentration of total suspended particulate matter at each monitor before and during development.

> H_o: There is no significant difference in the concentration of total suspended particulate matter between the control and the treatment sites.

These hypotheses will be tested on an annual and seasonal basis by statistically comparing the geometric means between data sets using analysis of variance techniques. Another important analysis is the comparison of particulate data with onsite meteorological and site activity data, using multiple regression techniques. This allows inferences to be made concerning the sources and causes of high particulate concentrations. As mentioned earlier, the sources of particulates are expected to change as development progresses. The data analysis will serve as a feedback mechanism to suggest adjustments to the monitoring program as well as to indicate the need for additional controls.

The particulate data are reviewed on a quarterly basis, and a report satisfying the requirements of the conditional PSD permit is submitted to the ~~A~~OSO and EPA.

C. Special Studies

1. Objectives

The objective of this section is to discuss techniques that go beyond the traditional air quality measurements to better characterize and understand the transport and dispersion of air pollutants in the area around the tract. The

primary emphasis at this point will be to understand the local meteorology and its influence on the dispersion of tract emissions, so these special studies are more appropriately presented in the meteorology section. These studies, which will help to improve our knowledge of the air quality impacts of retort emissions, are mentioned here because they are directed toward air quality assessments, even though they primarily involve a study of meteorological factors.

2.2 SOURCE EMISSION MONITORING

Permits and approvals must be obtained prior to construction and operation under the following regulations:

- Federal Prevention of Significant Deterioration of Air Quality Regulations (Clean Air Act amendments, 1977)
- Colorado Air Quality Control Regulations (Regulation 3) (Colorado Air Pollution Control Commission, 1975)

The development of Tract C-a is a prototype oil shale development project and the specific requirements for source emission monitoring programs cannot as yet be defined. The RBOSC source monitoring program will consider the pollution control devices employed, stability of operation and the relative significance of each pollutant. Extensive discussions will be held with the OSO and other regulatory agencies as the engineering monitoring design progresses. Source monitoring and stack sampling that are needed to comply with the terms of permits and approvals will be included in the final design. Sampling ports and access facilities will be installed on each source which is controlled by air pollution control devices.

A specific COA will require submittal of a process stream and emission monitoring program.

3.0 METEOROLOGICAL STUDIES

The climatology of the area was described in the Final Environmental Baseline Report (RBOSP 1977). Briefly, the climate can be characterized as semi-arid, with hot summers and moderately cold winters. Severe weather is very uncommon in the region. The skies are clear most of the year, and the humidity is generally quite low. The combination of bright sunshine and strong nocturnal radiational cooling leads to large diurnal temperature changes. Thus, valley winds are quite common in the area.

The local climate is important because the tract is intersected by several gulches, resulting in large topographic variations conducive to the development of mountain-valley winds. These local winds can have a significant influence on the dispersion of pollutants in the atmosphere. It has been noted, both in the 1976 tracer test and the monitoring data, that inversions occur frequently in the gulches. As a result, if pollutants enter the gulch system, they will tend to stay there, producing locally high concentrations. Thus, the interactions and coupling between the mesoscale and local winds are very important in determining the ambient air concentrations.

The upper air studies during the baseline period showed that the average mixing height at Site 1 varies from 600 feet above ground level during the fall to 3100 feet above ground level during the summer.

The matrix analysis assumed that tract development would have no effect on the meteorological parameters, with the possible exception of the atmospheric water vapor content (measured by relative humidity or dew point). As a result, the primary influence and importance of the meteorology at the tract is in an indirect role by influencing the dispersion of pollutants.

3.1 AMBIENT MONITORING

A. Objectives

- To develop a climatological data base, which can be used by discipline specialists studying the tract
- To develop a meteorological data base that can be used in atmospheric dispersion analysis
- To determine if meteorological conditions influencing atmospheric dispersion are similar during the baseline and subsequent development

B. Methods

1. Parameters

The following parameters are being measured as a continuation of the baseline data acquisition program:

- 10 m and 60 m wind direction
- 10 m and 60 m wind speed
- 10 m ambient temperature
- 10 m and 60 m temperature differential Evaporation ?
- Precipitation
- Solar radiation
- Dew point
- Barometric pressure
- Snow depth and accumulation

2. Monitoring Locations and Schedule

Figure 2-1 illustrates the meteorological monitoring locations currently active or planned around the tract. Table 3-1 lists the baseline monitoring schedule, and Table 3-2 lists the current or planned monitoring schedule.

Table 3-1. Baseline Meteorology Studies Monitoring Schedule

Parameter	Location	Monitoring Dates	Frequency
Wind Speed (10 m)	Sites 1,2,3,4	Feb. 1975 - Jan. 1977	Continuous
Wind Direction (10 m)	Sites 1,2,3,4	Feb. 1975 - Jan. 1977	Continuous
Wind Speed (30 and 60 m)	Site 1	Feb. 1975 - Jan. 1977	Continuous
Wind Direction (30 and 60 m)	Site 1	Feb. 1975 - Jan. 1977	Continuous
Ambient Temperature (10 m)	Sites 1,2,3,4	Feb. 1975 - Jan. 1977	Continuous
Ambient Temperature (30 and 60 m)	Site 1	Feb. 1975 - Jan. 1977	Continuous
Temperature Differential (10-60 m)	Site 1	Feb. 1975 - Jan. 1977	Continuous
Precipitation	Sites 1,2,3,4	Feb. 1975 - Jan. 1977	By event
Barometric Pressure	Site 1	Feb. 1975 - Jan. 1977	Weekly
Solar Radiation	Site 1	Feb. 1975 - Jan. 1977	Continuous
Relative Humidity	Site 1	Feb. 1975 - Jan. 1977	Continuous
Snow Depth & Accumulation	Sites 1,2,3,4	Feb. 1975 - Jan. 1977	By event

Table 3-2. Current Meteorology Studies Monitoring Schedule

Parameter	Location	Monitoring Dates	Frequency
Wind Speed (10 m)	Sites 1,2,3,7**	Sept. 1977	Continuous
Wind Direction (10 m)	Sites 1,2,3,7**	Sept. 1977	Continuous
Wind Speed (60 m)	Site 1	Sept. 1977	Continuous
Wind Direction (60 m)	Site 1	Sept. 1977	Continuous
Ambient Temperature (10 m)	Sites 1,2,3,7**	Sept. 1977	Continuous
Temperature Differential (10-60 m)	Site 1	Sept. 1977	Continuous
Precipitation	Sites 1,2,3,7**	Oct. 1977	By event
Barometric Pressure	Site 1	Jan. 1978	Weekly
Solar Radiation	Site 1	Sept. 1977	Continuous
Dew Point (10 m)*	Site 1	July 1978	Continuous
Snow Depth & Accumulation	Sites 1,2,3,7**	Nov. 1978	By event

* Relative humidity data were collected between Sept. 1977 - July 1978

** Site 7 to be activated during Summer, 1981

Need collection of evaporation data.

Meteorological data have been collected since the beginning of the baseline at Sites 1, 2 and 3 (with the exception of the seven-month interim period, when only Site 1 was operational). Site 1, equipped with a 60 m tower, is the most heavily instrumented site. Eleven parameters are currently being measured there (Table 3-2). Five parameters, including wind speed, wind direction, and ambient temperature, are measured at monitoring Sites 2, 3 and 7. Each of these sites are equipped with a 10 m tower.

The location of Sites 1, 2 and 3 are unchanged from the baseline studies and thus allow temporal as well as spatial data analysis. The primary use of the meteorological data will be in the interpretation of the air quality data. Consequently, the meteorological data are collected at the same locations as the air quality data.

Site 7 will be added during the summer of 1981, and will be located at the point where there is a likelihood of maximum air quality impact from the Lurgi surface retort project. The Hi-Vol and meteorological monitoring system at Site 7 will be established approximately 21 months in advance of the anticipated startup of the Lurgi retort, and approximately 18 months in advance of the activation of the air quality monitors. The meteorological data will be used to better define the low level flow patterns in the vicinity of the Lurgi retort before the air quality station is activated. In addition, the meteorological data will be useful in evaluating the Hi-Vol data.

Both the schedule and monitoring locations are subject to periodic review. If analysis of the air quality or meteorological data during the MDP monitoring program indicates that a change or addition to the monitoring network is necessary, appropriate modifications will be implemented after concurrence from the AOSO.

3. Monitoring Frequency

Meteorological parameters are monitored continuously by the automatic digital data acquisition system, backed up by the strip chart recorders. The data acquisition system scans each parameter approximately 12 times each minute and

computes an interim fifteen-minute average. The average value is recorded on magnetic tape at the end of each quarter hour. Hourly averages are computed from the interim averages during data reduction, in a similar manner to the calculation of air quality data.

4. Data Collection Techniques and Instrumentation

The present meteorological sensors for wind speed and direction have performance specifications which meet or exceed the stringent requirements of the Nuclear Regulatory Commission (NRC) Regulatory Guide 1.23 (NRC 1972). To maintain these specifications, these sensors are replaced semi-annually with identical units calibrated by the manufacturer, which are traceable to the National Bureau of Standards.

The temperature sensors are platinum resistance elements that have specifications which meet or exceed the requirements of NRC Regulatory Guide 1.23. To maintain the accuracy of the temperature system, the system is calibrated semi-annually against a certified mercury thermometer in absolute and differential temperature baths.

The dew point measurement instrument is factory calibrated to an accuracy which exceeds the requirements of NRC Regulatory Guide 1.23. The accuracy of the dew point sensor is maintained by proper servicing in the field.

The Belfort weighing bucket recording precipitation gages are calibrated semi-annually by adding precisely measured volumes of distilled water and checking the instrument response. The accuracy is maintained by keeping the collectors clean, and by keeping the mechanical mechanisms clean and free of insect intrusion. The wedge precipitation gages, which are permanently calibrated at the factory, are periodically checked to insure that they are clean and their exposure is satisfactory.

The solar radiation sensor is recalibrated at the factory annually. The accuracy is maintained by keeping the collector clean and the field of view unobstructed.

The recording devices are voltage operated and are calibrated with certified test equipment by applying a series of test voltages that permit the determination of sensitivity and linearity.

The geographic azimuth accuracy of the wind direction sensors is established with sighting telescopes using surveyed landmarks. Snow depth and accumulation are measured daily when snow is present by reading the depth on a standard metric ruler. Notes on new snowfall are also recorded.

5. Data Handling and Quality Assurance Techniques

The meteorological data are recorded on magnetic tapes at the site concurrently with the air quality data. The tapes are returned to the data center for computer listing, scaling and data fill-in from strip chart reduction, when required. The new data are reviewed for reasonableness prior to processing.

One hour of randomly chosen analog meteorological data is reduced every other week and compared with the data from the automatic digital system as a check to insure that the digital system is functioning properly.

Copies of the calibration data are forwarded to the analyst responsible for the monitoring system, where they are reviewed. If the review indicates that the data are in need of correction, this is done at that time. The data are then printed out in a final listing semi-annually and reviewed for reasonableness. Permanent storage of the data is on magnetic tape with a SAROAD leader.

C. Experimental Design and Data Analysis Procedures

The principal utility of site meteorological data is its application in interpreting observed changes in air quality. However, the data set is compared with baseline data to insure that it is representative. The comparison is as follows:

H_0: There is no significant difference between meteorological conditions measured during baseline studies and during the development phase.

The hypothesis will be tested by performing analyses identical to those of the baseline studies and include the following:

- Annual and seasonal wind roses for each sensor at each location.
- Annual and seasonal maximum, minimum and mean values.
- Monthly, seasonal, annual and event precipitation totals.
- Frequency of occurrence of stability class derived from ΔT data
- Joint frequency distribution of wind speed and direction by stability class on an annual basis

These statistics will be compared for both periods to determine if the data sets are similar.

Because the meteorological data system is designed to meet the stringent NRC Regulatory Guide 1.23 requirements, it will generally exceed the requirements of the EPA for monitoring data. The collected data should serve as a vital data set for use in dispersion analyses, and for use in special studies of the air quality data. It is important that the data base be of maximum utility. Consequently, the monitoring program will be periodically reviewed in light of the results of the analyses and projected future requirements.

The air studies data base will be available to the other investigators working on the tract. Close liaison will be maintained to assist these workers in providing or interpreting the meteorological data for use in their own specialities. Snow depth and accumulation data will be made available to biologists and hydrologists studying the tract for assessment in their particular disciplines.

3.2 SPECIAL STUDIES

A. Visibility

The Clean Air Act, as amended in 1977, declared that the prevention of visibility impairment from manmade air pollution is a national goal in mandatory Federal PSD Class I air quality areas. Although the oil shale tracts are Class II areas, a mandatory Class I area, the Flat Tops Wilderness Area, is 80 km ~~from~~ east of the tract. Changes in visibility are, therefore, a concern.

Visibility measurements were made during the baseline by using densitometers to determine the visual range on photographic exposures of identified geographical locations at a number of known ranges from the camera. Measurements were taken over a period of two years. In general, visibility at the site was excellent, but there was a high variability on both a daily and seasonal basis. The greatest seasonal difference in mean visual range was between the Spring and Fall seasons, with the latter having the greater range. Therefore, when the visibility program was continued after tract development began, the measurements were taken in the Spring and Fall of each year. Due to the large seasonal and diurnal variation, the number of samples required to obtain a representative sample is relatively high.

1. Objective

To provide measurements of visibility such that trends in the data can be distinguished from seasonal or diurnal fluctuations.

2. Methods

The program has included photometric photometry and telephotometers in a cooperative program with Tract C-b during 1978, 1979, and 1980. In November 1980, the EPA finalized the visibility regulations. The visibility monitoring program will be modified as necessary to comply with these new regulations and improvements in monitoring technology. It is anticipated that the cooperative program with Tract C-b will be continued. Any program modifications required

by the regulations or evolving technology will be fully discussed and agreed upon by the AOSO before implementation.

3. Experimental Design and Data Analysis Techniques

Both the experimental design and the data analysis techniques will depend upon the type of visibility program implemented in 1981. Nonetheless, certain design criteria must be met. In particular, sufficient measurements must be taken to insure reproducibility and to distinguish trends in the data from data variability.

B. Noise

Noise levels measured during baseline indicated that the background levels were low. Average measurements ranged from 24 to 51 dB with occasional peaks above this maximum due to airplane overflights and wind interference. Development on tract is anticipated to result in increased noise levels in the immediate vicinity of ongoing activities and near roadways as a result of increased traffic flow. Wildlife, especially big game animals, are expected to become acclimated to the noise within a short period of time and to resume normal activity patterns except in areas immediately adjacent to the mine site and in areas where the noise source is erratic.

MSHA and State of Colorado regulations relative to worker exposure to noise and ambient levels are stringently adhered to on Tract C-a. Qualified tract personnel monitor noise on a regular basis and impose restrictions on workers and equipment as necessary to assure compliance with applicable regulations. This program is conducted independently of the environmental studies and is not discussed herein. A description of mine worker safety regulations and procedures are available on Tract C-a for inspection upon request. The noise program discussed below addresses the environmental aspects of the noise program.

1. Objectives

Regulations regarding allowable noise levels have been promulgated for the safety and well being of humans. None of the existing regulations apply to effects of noise on wildlife, although some research has been conducted in this area (EPA 1971). The objectives of the environmental noise program are to provide the following:

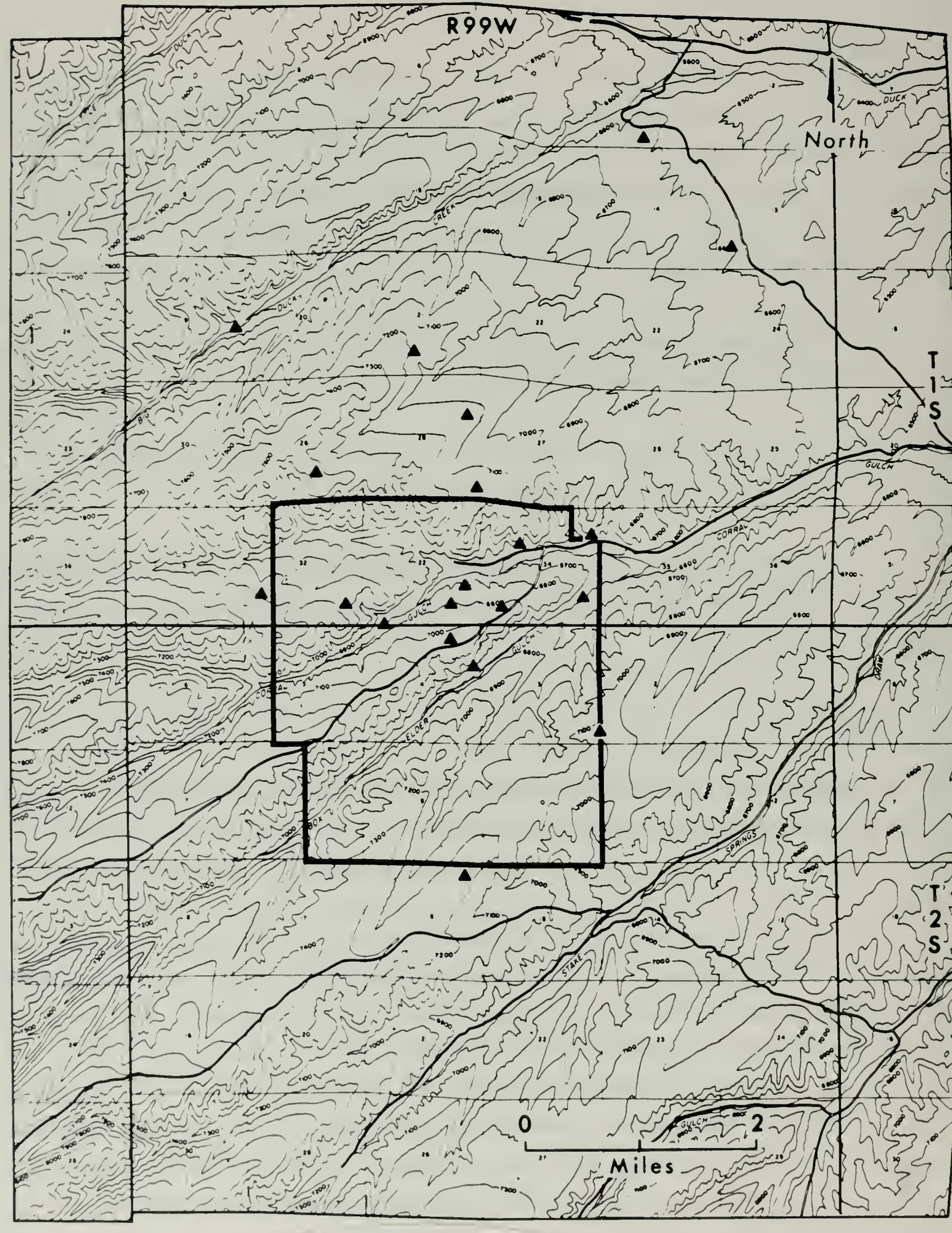
- Provide a data base on relative noise levels at various distances from the sources on tract

- Determine maximum noise levels at the tract boundaries likely to occur as a result of tract operations

- Provide data for use by wildlife biologists in assessing the overall impacts of tract development on wildlife behavior and use of the study area.

2. Methods

The experimental design set up for the quarterly noise measurements for the MIS program consisted of 16 survey locations in concentric rings around the process site. As a result, an estimate was obtained of the magnitude and extent of influence of the MIS process on the ambient noise levels. The results have shown that the noise caused by tract activity rather quickly becomes indistinguishable from the background sounds. The survey program will be altered to measure the noise impacts from the Lurgi retort. Six new sites will be established in concentric semicircles north of the Lurgi retort, as well as one site near the future location of the retort (Figure 3-1). Three sites located on the southern boundary of the tract will be deleted from the program, since they provide only redundant data on background noise levels available from other sites. The new program, to be initiated in 1981, will have a total of 20 sites.



off-tract property

Figure 3-1
Environmental Noise Monitoring Sites

Each permanent site will be flagged and will be monitored once each quarter. In addition to these quarterly measurements, opportunistic readings will be taken in construction or mining areas and at several selected off tract locations during peak levels of activity to determine the sources and levels of noise and the distances at which the sounds can be heard.

Sound level readings will be taken with a General Radio Sound Level Meter, Type 1565B. The accurate range of this instrument is 30 to 130 dB. The sound level meter will be calibrated before and after each sampling day with a General Radio Sound Level Calibrator operating on a frequency of 1000 Hz±1%. Wind speed will be determined with a handheld anemometer. Wind direction will be estimated with the aid of a compass.

The sound level meter will be calibrated using the Sound Level Calibrator before each survey. Wind speed (mph), wind direction (degrees) and time will be recorded at the start of each survey. Highest and lowest values on the meter during a 20-second period will be recorded for each site. Measurements will be repeated five times. Comments noting unusual circumstances (e.g., jets overhead) and general conditions during the reading will be recorded.

Sound level readings will be reported as highest and lowest range for each of the five readings at each site and as the sound level average of all five sites. Values will be reported in decibels, a weighting scale (dBA).

3. Experimental Design and Data Analysis

Sound data collected as a result of this survey will be made available to wildlife biologists studying the tract for their use in assessing the impacts of development on the wildlife in the area. This information will be used in conjunction with activity data to assess long-term trends in deer use, songbird densities and other population parameters. These assessments will be largely judgemental in nature since the data are not quantitative and cannot be statistically assessed.

C. Short-Term Studies

The complex local wind flow patterns associated with rough terrain, such as found in the vicinity of Tract C-a, are not well understood. Because these flows can have a strong influence on the dispersion of emissions from a source, accurately predicting the air quality impacts in complex terrain is a difficult task.

Consequently, a series of short-term intensive experiments are planned in the immediate vicinity of Tract C-a to improve our understanding of the local meteorology and its relationship to the general mesoscale circulation. The overall objective of these studies is to improve our ability to predict the dispersion of emissions from Tract C-a, and to evaluate the adequacy of current air quality models. It is planned to interface this program with EPA's efforts to build a regional complex terrain model, including field studies such as the Yellow Creek Meteorological Study of 1980.

Although RBOSC has several years of very complete surface meteorological records, an important area which needs further investigation is the interactions between the surface and upper air wind flows - the coupling of the winds in complex terrain. The problem in studies of this type is that by their nature they are short-term, intensive investigations and must be carefully planned and executed to collect valid and representative data.

Consequently, in order for such a study to be effective, RBOSC will require involvement in the planning stages from both the ~~A~~OSO and EPA. The most effective approach would be a joint study, with assistance from ~~A~~OSO and EPA personnel in both the planning and execution stages.

RBOSC's preliminary plan is to incorporate both smoke releases and tethersonde measurements in a small mobile laboratory. This type of instrumentation has found wide acceptance and use in studying the meteorology of complex terrain (Barr et. al., 1980; Orgill et. al., 1980; Whiteman and McKee, 1978; Whiteman and McKee, 1979). Measurements are planned at several locations around Tract C-a, including the MIS process site, the Lurgi retort process site (and the

surrounding area), Corral Gulch and the new meteorology/air quality monitoring site (Site 7). Experiments will be conducted, where feasible, during both nocturnal drainage conditions and daytime convective conditions. The representativeness of the short-term studies can be estimated by taking measurements during each season. The mobility of the instrument package will also allow a large number of areas of interest to be studied.

Data analysis of the tethersonde measurements should greatly improve our understanding of the coupling between the surface and upper air flows, as well as the existence and extent of shear layers in the boundary flow regime. Photographic documentation of the smoke releases will improve our qualitative understanding of trajectory flows and dispersion patterns from selected point sources.

The results of these studies will be fourfold:

1) They will provide data to help evaluate the adequacy of the air quality dispersion models that have been used at Tract C-a.

2) They will provide data that can be used, in conjunction with EPA's efforts to develop better air quality models appropriate to the area's complex terrain.

3) They will assist in locating and addressing the adequacy of the ambient air monitoring sites.

4) They will provide assistance in future plant siting decisions by suggesting favored areas of maximum local dispersion and problem areas of poor potential dispersion capability.

As discussed above, RBOSC is committed to the program described in general terms above. Exact details cannot be given at this time, since an effective program will depend upon input from the AOSO and EPA, as well as preliminary results from the Yellow Creek Meteorological Study.

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4.0 TERRESTRIAL STUDIES

The RBOSC MDP terrestrial monitoring program is based on the results of the intensive two-year baseline program conducted between 1974 and 1976 and a detailed assessment of the terrestrial impacts expected to result from oil shale development on Tract C-a. The terrestrial baseline program was conducted on Tract C-a and the area within five miles of the tract boundary and included detailed soils, vegetation and wildlife studies. A complete discussion of the results and interpretation of the terrestrial baseline program is presented in the Final Environmental Baseline Report (RBOSP 1977).

The analyses performed on the Tract C-a terrestrial baseline data (RBOSP 1977) suggest a high degree of heterogeneity within the soil and vegetation systems. Cluster analysis of soil characteristics indicated that 85 percent of the sample sites were similar but the principal component analysis of soil parameters indicated that it is not possible to isolate one or two soil traits as indicator or control factors. As a result, the soils monitoring program selected for MDP operations has been deleted from the terrestrial studies pending completion of on-going research. This research is expected to better delineate sampling site selection and techniques applicable to commercial operations.

The eight vegetation types studied during the baseline period exhibited an inherent complexity and variability between sampling locations. Community coefficient and percentage similarity measurements were analyzed to determine the effort required to adequately sample vegetation for the monitoring program.

Major faunal elements surveyed included small mammals, large mammals, mammalian predators, avifauna, reptiles and amphibians and invertebrates. These faunal groups were analyzed with respect to species composition, abundance of individuals, species diversity and seasonal variation in composition, abundance and diversity. Of the faunal groups surveyed, the small mammals, avifauna and large mammals are most important; the other three groups have been excluded from the monitoring program because of their lesser importance, limited presence on the Tract C-a study area or the inability to adequately assess their numbers. Although the habitats and associated fauna on Tract C-a are ecologically important, they are not unlike other portions of the Piceance Basin.

An assessment of MIS impacts by means of a qualitative "cause/effect" matrix analysis was conducted to determine impacts expected to result from MIS development. All known proposed actions affecting environmental parameters were considered. A similar process was used in asessing potential combined impacts of the MIS and Lurgi facilities, although a formalized matrix analyses was not prepared.

Environmental parameters which are expected to be affected by developmental activities, or are ecologically or politically important, have been included in the terrestrial monitoring program.

4.1 ABIOTIC MONITORING

A. Soils

Analyses of the baseline soils data indicated that soil traits which can be identified as "indicators" cannot be verified for Tract C-a and the vicinity. Soils represent a secondary transport medium in the ecosystem, however, being the major contributor of chemical constituents for uptake by plants. For this reason impacts on the soil stratum need to be identified and quantified to the highest degree possible. Changes in trace metal content and conductivity levels are the most probable impacts of development that can be measured with a reasonable degree of accuracy. Dispersion of particulate matter from stacks and salt drift from cooling towers could result in discernible changes in soil trace metal content and conductivity during commercial operations. However, because the emissions are expected to be minimal during the operation of demonstration facilities, and because further research is needed to identify reliable "indicators", monitoring will not be undertaken during the Lurgi Demonstration Project. Soil trace metal content and conductivity studies will commence with start-up of a commercial operation; and will be conducted in an area to be determined based on analysis of probable impact areas (see Table 4-1).

EPA also interested in sulfur compounds.

1. Trace Metal Accumulation

a. Objectives - The prime objective of the trace metal accumulation study is to determine if releases of particulate matter from operations on tract have appreciably affected the concentration of these metals in soils of the area. The second objective is to determine if metals accumulated in soils have been taken up by plants.

b. Methods - RBOSC will monitor the progress of on-going research pertinent to sampling for trace metals. Information gained from this research will be used to design a trace metals sampling program for commercial operations. No trace metals survey will be conducted until commercial operations.

Base initiation of studies on development of a statistical sound sampling design (klusman) and detailed air quality modeling to determine the treatment site

Table 4-1. Terrestrial Studies Monitoring Schedule

Parameter	Location	Start Date	Frequency
Soils Trace Metals Studies		Commercial Operations	
Soil Conductivity Studies		Commercial Operations	
Vegetation Mapping	Tract C-a & 5-mile Perimeter	Aug. 1978 *	Every 3rd year
Vegetation Stress	Anticipated impact areas	June-July 1979	Annually
Vegetation Phytosociological Studies	See Figure 4-1	May-June 1979	Once/3-yr period Rotation Basis
Range Productivity & Utilization	See Figure 4-1	April 1978 (establish plots)	Annually (in Sept.)
Browse Condition & Utilization	See Figure 4-1	May 1978	Annually
Small Mammals	See Figure 4-1	May-June 1979	Annually
Avifauna Studies	See Figure 4-1	May-June 1979	Annually
Mule Deer - Density Studies	Tract C-a and 3 mile Perimeter	Sept. 1977	Semi-annually (May, Sept.)
Mule Deer - Road Kill Studies	County Road 24	Feb. 1979	Weekly During Peak Migrations
Feral Horse Abundance	Tract C-a & 3-mile Perimeter	Jan. 1978	Annually

* 1978 aerial photography was conducted in August; however, subsequent flights will be scheduled for June-July

These not specifically shown on Fig 4-1

2. Soil Conductivity Studies

a. Objectives - Concentrations of salt drift from cooling towers are projected to be low during operation of the demonstration facility. Therefore, conductivity studies will not be triggered until just prior to the commercial phase, since the source of impact will not exist until that time.

b. Methods - Methods of sampling soil conductivity will be developed at the time that commercial facilities are designed. Ongoing research pertaining to trace metals will aid in the sampling design of these studies.

4.2 BIOTIC MONITORING

A. Vegetation

Detection and evaluation of impacts on vegetation is anticipated to be difficult due to the heterogeneity found in the vegetation types on Tract C-a. Analyses of plant species composition (community coefficient) and abundance (percentage similarity) indicate a high degree of complexity and variability between locations sampled during the baseline studies. Such inherent variability makes it difficult to separate normal annual fluctuations from those caused by oil shale development. Therefore, the vegetation program includes the following studies in order to facilitate interpretation of the data:

- Vegetation Type Distribution
- Phytosociological Studies
- Range Productivity and Utilization
- Browse Condition and Utilization

These studies were selected to detect changes anticipated to result from MDP activities; as indicated by the detailed MIS impact assessment and subsequent Lurgi impact analysis.

1. Vegetation Type Distribution

a. Objectives - Construction and operation at Tract C-a may affect the local distribution of vegetation. This study is designed to monitor the distribution of vegetation in the tract vicinity and to detect any large-scale changes in the distribution of vegetation types resulting from Tract C-a development. This qualitative program permits RBOSC to monitor Tract C-a and the surrounding area to determine if impacts not previously predicted are occurring. If such impacts occur, then quantitative programs will be designed to determine the nature and extent of the detected impact.

b. Methods - Color aerial photography (1 inch = 2,000 feet scale) of Tract C-a and the area within a five-mile radius is taken at three-year intervals. These photographs will be compared to the RBOSC vegetation map (RBOSP 1977) and earlier color aerial photographs to determine if changes have occurred in the distribution of vegetation types. If changes are detected, the vegetation map will be modified to reflect them. Color aerial photography is available for 1974 and 1978.

c. Experimental design and data analyses - This program is designed to provide qualitative information on vegetation distribution since statistical analyses are not appropriate. Vegetation distribution data are presented on a vegetation map which is used as the basis for calculating, by planimetry, the acreage of each vegetation type in the study area. Vegetation distribution is compared between sample periods to determine the extent and significance of any changes in habitat resulting from the development on Tract C-a and adjacent areas. These data are not computer compatible and are not stored on computer tape.

2. Vegetation Stress

a. Objectives - Disturbances related to construction and operation at Tract C-a and adjacent areas may affect the condition of plants without modifying the distribution of plant communities. This study is designed to detect vegetation stress which may be related to air pollutants or changes in the ground water or surface water regimes. The vegetation stress study provides qualitative data over portions of Tract C-a and surrounding areas which may be affected by project operations.

b. Methods - Color infrared (CIR) aerial photography (1 inch = 500 ft scale) is taken on an annual basis to determine stress conditions. Photographs are compared with those from previous years to assess variations in moisture regime and, to the extent possible, stress related to air pollutants. To facilitate this qualitative, visual comparison, color balance of photographs is matched to that of previous years.

It is expected that variations in the CIR transparencies between years will occur as a result of variations in meteorological conditions at the time of the flight, in film emulsions, and in processing. The combined effect of these variations would make quantitative computer analyses of CIR photography difficult. RBOSC will continue to evaluate ongoing research relating to computer analysis of CIR photography, to assess its applicability to these studies.

CIR photography at the aforementioned scale is presently available for 1979 and 1980. Ground control points were established prior to the 1979 flights to allow for better definition of photographic points relative to ground features.

c. Experimental Design and Data Analysis - Areas to be studied are determined annually in cooperation with the AOSO. If stress conditions are identified, an additional sampling program will be initiated upon approval by AOSO to determine the extent and cause of damage.

Analysis of photographs involves qualitative, visual comparisons of between-year changes in moisture regime. Changes which are identified are mapped and included in year-end reports.

3. Phytosociological Studies

a. Objectives - The objective of the vegetation phytosociological studies is to monitor species composition and cover in the major vegetation types expected to be affected by oil shale development. Such information will provide quantitative data which will complement the information on the distribution of major vegetation types and provide continuity with similar information collected during the baseline period. Additional monitoring records will include photoplots.

b. Methods - Phytosociological studies provide data on the following parameters:

- Species Composition
- Cover (%) of Herbaceous Species
- Density of Woody Species

Phytosociological studies are conducted in pinyon-juniper and sagebrush vegetation types in a control site south of Tract C-a (Location 6), and in treatment sites on Airplane Ridge (Location 5) and a new site on Dead Horse Ridge (Location 7) (Figure 4-1). These sites correspond to the sampling locations for the small mammal and avifauna studies. Final siting of Location 7 will occur during the 1981 field season.

Phytosociological sampling is conducted in May-June once every three years in a specific vegetation type on a rotating basis. During the initial sampling period in each type, density and cover of woody species and herbaceous cover is determined; thereafter only herbaceous cover is measured. Sampling began in May - June 1979 in the pinyon-juniper habitat type in Locations 5 and 6.

Density of woody species is determined in five permanently established belt transects (100 m x 6 m). This modified line-strip method was used to determine density of woody species during the baseline program. In addition, a line-transect (100 m length) will be established in each of the five belt transects (total 500 m) to determine cover of each woody species.

Herbaceous cover is measured within 20 plots (1 m x 1 m) permanently established within each belt transect (total 100 plots per vegetation type in each study location).

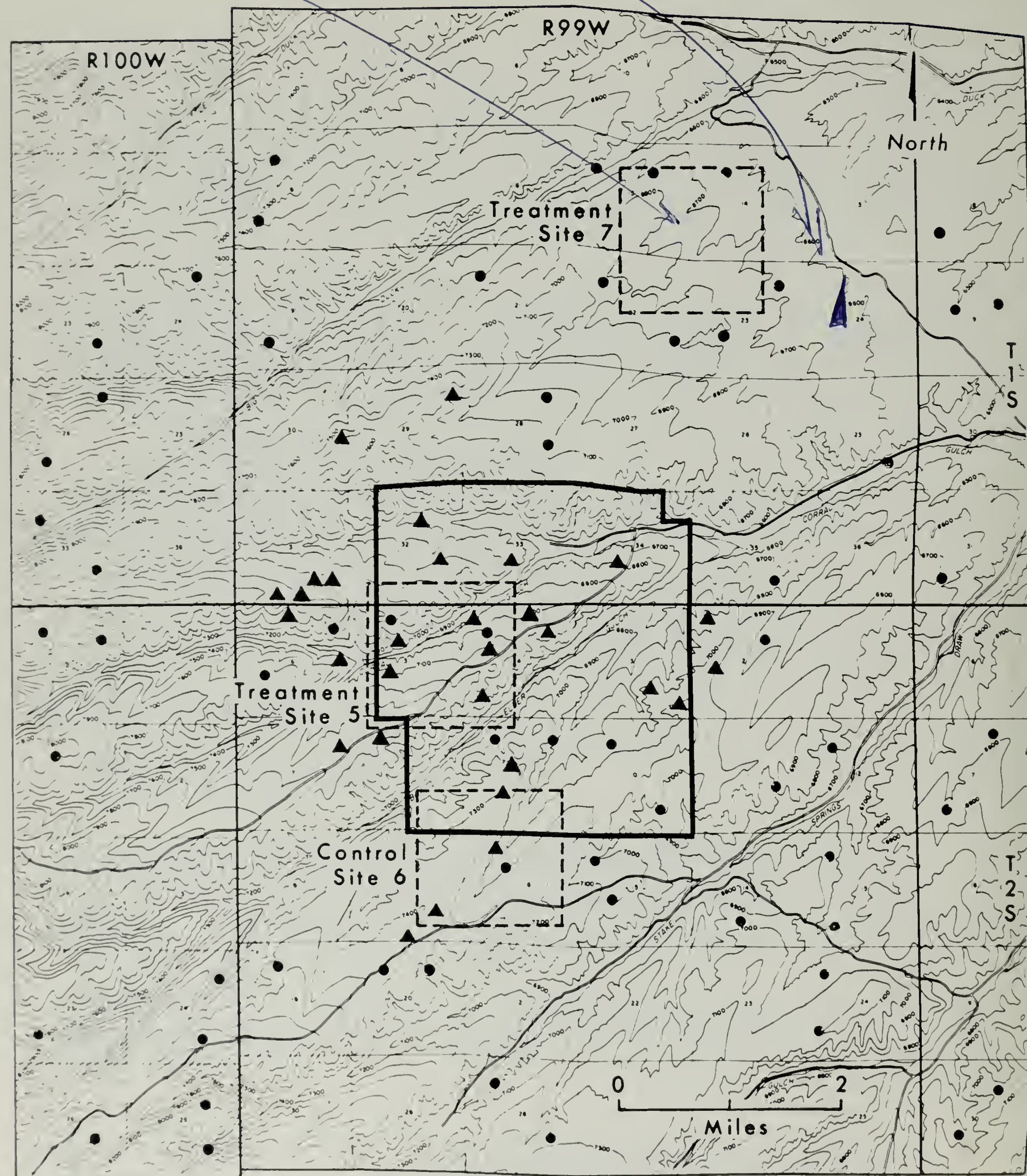
At each control and treatment site within each vegetation type, photoplots are established at each belt transect to monitor changes in the vegetation. Photographs are taken annually during May-June from permanently marked locations.

Cover and density data are entered and stored on 9-track, 1600 bpi magnetic tape and all data analyses are performed by computer. Methods follow standard quality assurance procedures.

c. Experimental Design and Data Analysis - The phytosociological studies are designed to test the following hypotheses:

studies in treatment site?

with treatment site 7



f-tract property

● Mule Deer Pellet Group Sample Unit

▲ Range-Browse, Productivity & Utilization Study Site

[ ] Intensive Study Areas

Figure 4-1
Terrestrial Ecology Monitoring Sites

H_0: There is no significant difference in herbaceous cover (%) within a vegetation type:

1. among three locations
2. among transects within each location
3. before versus during development

Percentage data for cover are transformed to arcsines (Sokal & Rohlf 1969) and analysed by the following ANOVA:

Source of Variation	Degrees of Freedom	F-Test
A. Location 1 = 3	a-1 = 2	A/B
B. Transect within location b_i = 5	$a(b_i-1)$ = 12	B/F
C. Phase c = 2	c-1 = 1	C/F
D. Location x Phase	(a-1)(c-1) = 2	D/F
E. Transect within Location x Phase	$a(b_i-1)(c-1)$ = 12	E/F
F. Error (N = 20 samples per transect	$ab_ic(n-1)$ =570	
Total	$(nab_ic)-1$ =599	

This nested or hierarchical, two-way ANOVA is used to detect differences in the percent herbaceous cover between three locations (main effect A), among five transects within each location (nested effect B), and between phases (before versus during development, main effect C). The interaction effect (D) tests differences among location by phase, while the interaction effect (E) tests the differences among transects, within each location by phase.

The F-ratios (in the aforementioned ANOVA) test the homogeneity of the variances within each treatment (A-d); thus significant F tests imply that not all treatment combinations within an effect come from the same sample population. Therefore, significant interaction and main effects will then be tested to identify differences among means within response variables using a Duncan's multiple range test.

Because the woody species data will be collected only once, these data are not amenable to Analysis of Variance techniques. These data will serve as additional

"baseline" information for the control and treatment sampling sites and will be used in the interactions analyses with the wildlife data. If impacts are detected by the photoplot or vegetation distribution monitoring programs, then subsequent woody species sampling programs will be initiated.

3. Range Productivity and Utilization

a. Objectives - The development activities on Tract C-a and adjoining areas may affect the range conditions in the vicinity of these activities. Range productivity and utilization studies are designed to provide information on vegetative production which can be used to compare range productivity before and during development. Range utilization will also be determined, although this parameter cannot be used as an impact indicator since it is affected by stocking rates. Because the potential impacts are projected to be local, the range studies focus on areas on Tract C-a and vicinity that are adjacent to MIS and proposed surface retort facilities, and that were previously used for grazing.

b. Methods - The range sampling sites were selected at random in mixed brush, pinyon-juniper and sagebrush vegetation types in the same general location as the browse transects. The distribution of the interim range transects (mixed brush-5, pinyon-juniper-10, sagebrush-15) was modified in 1977 to establish 10 transects in each vegetation type. During the 1981 field season an additional five transects will be included in each of the three vegetation types. The locations of the existing 30 range sampling transects are presented in Figure 4-1.

Several transects are in different locations from the interim locations established for the earlier MDP monitoring. Transects which are located in close proximity to the open pit activities may be relocated to adjacent areas as development progresses. One transect was disturbed by tract activity and was replaced.

Forage is measured annually at the end of the growing season (August-September) (Table 4-1) by the double sampling method (USDA 1970).

An adequate sampling size was determined for each vegetation type. These estimates were calculated for each of the six sampling periods in 1975 and 1976 (RBOSP 1977). Based on 1.0 m x 0.5 m quadrats, an adequate sampling size (detection of ±10% of the mean 90% of the time) is 302 sample quadrats for mixed brush, 383 for pinyon-juniper and 403 for sagebrush. This extremely high number of sample quadrats is not practical or feasible for development monitoring, however. Sample size requirements to detect a difference of ± 25% of the mean 90% of the time are 64 for sagebrush, 49 for mixed brush and 61 for pinyon-juniper. The range productivity and utilization studies are designed to include 15 transects per vegetation type (10 plots/transect) or a total of 150 plots. This sampling intensity should detect a difference of ± 25 percent of the mean 90 percent of the time. The sampling intensity will be evaluated periodically and the program modified as necessary to maintain this degree of accuracy.

Five caged plots (1 sq. m. in size), and five unprotected plots (permanently marked) are located at 10-m intervals along each sample transect. The existing plots were permanently established in April of the first sampling year (1977). New plots will be established in April 1981. The caged plots are moved to new locations each April-May (Table 4-1). Sampling is done with a 1 sq m sampling loop on each of the unprotected plots. An ocular estimate is made of production (weight to the nearest gram) of the dominant grass and forb species (species making up 90% percent of the individuals) within the loop. Vegetation in the five protected plots is estimated in the same manner. Each species within the protected plots is then clipped, bagged separately, weighed green, and the weights are recorded. Species providing less than one percent of the biomass are recorded as being present, but are not weighed. Correction factors are calculated from the estimated green weights and actual green weights of the clipped plots.

$$\text{CORRECTION FACTOR} = \frac{\text{Actual Green Weight}}{\text{Estimated Green Weight}}$$

These correction factors are used to correct all estimated values. Clipped samples are oven-dried for approximately 24 hours at 105° C and weighed to obtain moisture percentages. All corrected estimates are then computed, using

these moisture percentages to obtain oven-dry forage productivity estimates.

Utilization is calculated as follows:

$$\text{Utilization} = \frac{\begin{matrix}\text{Average productivity} \\ \text{per ungrazed plot}\end{matrix} - \begin{matrix}\text{Average productivity} \\ \text{per grazed plot}\end{matrix}}{\begin{matrix}\text{Average productivity} \\ \text{per ungrazed plot}\end{matrix}} \times 100$$

Damage from insects or frost is qualitatively assessed. Any damage is recorded and an estimate of the percent of the sampled vegetation which is affected is made.

Data are entered and stored on 9-track, 1600 bpi magnetic tape and all data analyses are performed by computer. Field sampling and data handling are conducted according to documented quality assurance procedures.

c. Experimental design and data analyses - The range studies are designed to test the following hypothesis:

H_o: There is no significant difference in vegetative productivity within a given vegetation type:
1. among transects
2. between protected and unprotected plots
3. before versus during development

The range productivity data are analyzed by the following ANOVA to compare pre-development conditions with those during development. After one year of monitoring transects established during the 1981 field season, this ANOVA design will be changed to account for 15 transects (main effect A).

	Source of Variation	Degrees of Freedom	F-Test
A.	Transects a = 10	a-1 = 9	A/H
B.	Protected/Unprotected Plots b=2	b-1 = 1	B/H
C.	Phase c = 2	c-1 = 1	C/H
D.	Transects x Protected/ Unprotected Plots	(a-1)(b-1) = 9	D/H
E.	Transects x Phase	(a-1)(c-1) = 9	E/H
F.	Protected/Unprotected Plots x Phase	(b-1)(c-1) = 1	F/H
G.	Transects x Protected/ Unprotected Plots x Phase	(a-1)(b-1)(c-1) = 9	G/H
H.	Error (n = 5 protected/ unprotected plots per transect)	abc n-1 = 160	
	Total	nabc-1 = 199	

This three way ANOVA is used to detect differences in primary productivity among 10 transects in each vegetation type (main effect A), between protected and unprotected plots (main effect B), and between baseline and development (main effect C). The interaction terms test for differences between protected and unprotected plots by transect (D), differences among transects by phase (E), and differences between protected and unprotected plots by phase (F). Finally , the second order interaction term (G) tests for differences between protected and unprotected plots by transects and phase.

The F ratios in the ANOVA test the homogeneity of variances within each treatment; thus, significant F tests imply that not all treatment combinations within an effect come from the same sample population. Therefore, significant interactions and main effects will be tested with a Duncan's multiple range test to identify differences among means within the response variables.

Range utilization data are used as an indicator of grazing pressure in the tract vicinity. These data are not analyzed by the above ANOVA since significant differences between phases would not be indicative of impacts resulting from oil shale development.

4. Browse Condition and Utilization

a. Objectives - Tract C-a development may reduce browse availability and therefore affect animal distribution in the vicinity of Tract C-a. The browse condition and utilization studies are designed to provide browse use information for areas adjacent to Tract C-a development.

b. Methods - The browse sampling sites were selected at random in the same general location as the range transects. The distribution of the browse transects (mixed brush-5, pinyon-juniper-10, sagebrush-15) was modified in 1977 to establish 10 transects within each of these types. The locations of these 30 browse transects are shown in Figure 4-1. During the 1981 field season, five additional transects will be added in each of the three vegetation types, resulting in a total of 45 transects.

Browse sampling is conducted annually in early May after deer have migrated through the Tract C-a area (Table 4-1).

Browse condition and utilization is estimated along transects consisting of 25 individual permanently marked shrubs (USDI 1963). Transects are selected at random within each vegetation type.

Browse species sampled include: juniper (*Juniperus osteosperma*), pinyon pine (*Pinus edulis*), antelope bitterbrush (*Purshia tridentata*), snowberry (*Symphoricarpos oreophilus*), big sagebrush (*Artemisia tridentata*), true mountain mahogany (*Cercocarpus montanus*), and Utah serviceberry (*Amelanchier utahensis*).

During field sampling, five parameters are examined and recorded including:

Form classes:

1. All available, little or no hedging
2. All available, moderately hedged
3. All available, severely hedged
4. Partially available, little or no hedging
5. Partially available, moderately hedged

6. Partially available, severely hedged
7. Unavailable
8. Dead

Age Classes:

S - seedling - less than 0.3 cm basal diameter

Y - young - 0.3 to 0.6 cm basal diameter

M - mature - over 0.6 cm basal diameter

D - decadent - more than 25 percent of crown surface is dead

Leader Use Estimates:

Percent of twigs or leaders which are available and show use

Hedging Classification:

Classification based upon the length and appearance (hedging) of the previous year's growth (the two-year old wood):

1. None to light
2. Moderate
3. Severe

Availability:

Visual estimate of the percent of the plant available to deer as browse, i.e., that portion less than six feet high.

Damage from insects or frost is assessed qualitatively. Any damage is recorded and an estimate of the percent of the sampled vegetation which is affected is made.

Data are entered and stored on 9-track 1600 bpi, magnetic tape and all data analyses are performed by computer. Field collection techniques and data control procedures are outlined in the Quality Assurance Manual.

c. Experimental design and data analyses - The browse studies are designed to test the following hypothesis:

H_0: There is no significant difference in browse utilization of a specific plant species within a given vegetation type:

1. before versus during development
2. among seven potential browse species

The browse utilization data collected in the mixed brush, pinyon-juniper and sagebrush types are analyzed by the following ANOVA. Percentage data are arcsine transformed (Sokal & Rohlf 1969) prior to statistical analyses.

Source of Variation	Degrees of Freedom	F-Test
A. Species a = 7	a-1 = 6	A/E
B. Phase b = ~~3~~ 2	b-1 = ~~2~~ 1	B/E
C. Species x Phase	(a-1)(b-1) = 12	C/E
E. Error (n = 10 transects)	ab(n-1) = 189	
Total	nab-1 = 209	

This two-way ANOVA compares browse use within each vegetation type among seven plant species (main effect A) and before versus during development (~~nested~~ main effect B). The first order interaction term (C) tests for different browse use among species, by phase.

The F ratios in this ANOVA test the homogeneity of variances within each treatment, thus implying that not all treatment combinations come from the same sample population. Therefore, significant interactions and main effects will be tested with a Duncan's multiple range test to identify differences among means within the response variables.

Phase (main effect ~~A~~ B) will vary depending on the number of years of data being considered. The number of transects will be n = 10 for 1980 and 1981 but will increase to n = 15 in 1982 when two years of data are available.

Browse utilization data will be tested periodically to verify the number of transects necessary to detect a difference of $\pm$25 percent of the mean 90 percent of the time. The sampling intensity will be adjusted to achieve this detection level if necessary.

The browse condition data are class data which are not appropriate for ANOVA techniques. These data are summarized and qualitatively compared between years.

B. Fauna

The faunal elements expected to be most affected by oil shale activities include small mammals, avifauna and large mammals. Of these three groups, large mammals are also politically sensitive due to the status of the Piceance Creek deer herd and its important recreational value in western Colorado. Matrix analysis indicated that the abundance and distribution of these species are most likely to be affected. Therefore the following programs have been designed to monitor population parameters in important habitats on Tract C-a.

1. Small Mammal Studies

Intensive reviews of baseline data indicate that reliable small mammal population data such as density, age structure and species diversity are difficult and costly to obtain. Given reliable data, there is little agreement in the literature about the interpretation of even gross changes in population parameters (Snyder 1978). The baseline data program was therefore, discontinued in favor of a limited program that is designed to determine species presence and habitat affinity, and provide indices of relative abundance in important control and treatment habitats.

a. Objectives - To determine the presence and relative abundance (captures/trap night) of small mammals in sagebrush and pinyon-juniper habitats in control and treatment areas.

b. Methods - Parameters to be measured include:

- Species Presence
- Relative Abundance

Small mammals will be monitored in pinyon-juniper and sagebrush habitat types in a control area (6) just south of the tract boundary near air studies site 2, in a treatment area (5) on Airplane Ridge and in an additional treatment area (7) to be established in 1981 on Dead Horse Ridge near site activities (Figure 4-1).

Three to five transects are placed in each habitat type for each area. Each transect consists of two lines of ten Sherman live traps; lines and traps are 15 m apart. Bait consists of a mixture of peanut butter and seeds.

Sampling is conducted in late spring or early summer for three or four consecutive days. Trapped animals are identified to species, sexed, aged, marked and released.

The statistical detection level for this sampling intensity is a function of the number of captures; as captures increase the confidence interval will narrow. It is not possible to predict detection levels _a priori_ since capture numbers are not controllable.

Data are entered and stored on 9-track, 1600 bpi magnetic tape according to established quality assurance procedures. Field procedures and quality control measures are identified in the Quality Assurance Manual.

c. _Experimental Design and Data Analyses_ - The small mammal data are presented as relative abundance (captures per trap night) in sagebrush and pinyon-juniper habitats in the control and treatment areas. For each year of the program and for each habitat type, species found in both the control and treatment area are ranked according to their relative abundance. Spearman's Rank Order Correlation Coefficient is then calculated to determine the degree of independence between the control and treatment data. Coefficients of rank correlation are compared between years to determine if the relative abundance of small mammal species has changed as site development progresses.

The data will be used to test the hypotheses:

H_0: There is no significant difference in the rankings of the relative abundance of small mammal species on control and treatment areas within each habitat type when rankings are compared between years.

H_0: There is no significant difference in the rankings of the relative abundance of small mammal species among transects within a habitat type within a control or treatment area within the same year.

Interpretations of the small mammal data are constrained in several ways. The coefficients of rank order correlation provide an indication of the degree of independence of the relative abundance rankings of species in the control and treatment areas; there is no obvious rationale to explain the degree of independence other than the expectation that similar habitats should have similar small mammal populations.

Tests of the null hypothesis will indicate whether or not there are statistically significant differences in the coefficients of rank correlation between years; if the null hypothesis is rejected in the relative abundance rankings of small mammals on the control and treatment areas, these differences could be due to natural variation, "treatment effects", or sampling errors (e.g. differences in phenology between identical calendar dates during the two years). At best, the results of the small mammal sampling program will provide qualitative indices about possible effects of site development.

If significant differences between locations occur, a detailed analyses of other parameters sampled in these two locations will be initiated. This analysis will indicate if these differences reflect natural fluctuations or are also evident in soil and/or vegetation elements. If it appears that oil shale activities are negatively affecting population levels, more detailed small mammal studies (e.g. fall sampling) will be initiated.

2. Avifauna Studies

Previous RBOSC avifauna studies on Tract C-a included the determination of seasonal variations in songbird population composition, distribution and abundance

during the baseline program and studies on selected species and parameters during the interim program. There is little, if any, evidence, however, that avifauna sampling programs that are conducted within reasonable constraints of time and money can detect any except gross changes in bird population parameters or any of many possible natural abiotic or biotic causes (Wiens 1977).

The avifauna program is, therefore, designed to determine species composition and relative abundance in important control and treatment habitats.

a. Objectives - To determine species composition and relative abundance of birds in pinyon-juniper and sagebrush habitats in control and treatment areas.

b. Methods - Parameters which are measured include the following:

- Species Composition
- Relative Abundance

Avifauna are monitored in pinyon-juniper and sagebrush habitats in a control area (6) south of the tract boundary, in a treatment area (5) on Airplane Ridge and in an additional treatment area (7) to be established in 1981 on Dead Horse Ridge near site development activities (Figure 4-1). These control and treatment sites are the same as those being used for soil, phytosociological vegetation and small mammal studies. In addition, air studies Site 2 is located near the control area. The multiple sampling program at these two sites will permit future analyses of ecosystem interrelationships as described in Section 8.0

Avifauna are monitored by means of a modified Emlen transect method (Emlen 1971 and 1977). Two half-mile transects are run in each habitat type in each area during the breeding season each spring (May - June). Birds detected up to 200 feet from the transect line are recorded. Each transect is run three times during early morning hours.

The statistical detection level for this sampling intensity is a function of the number of bird observations; as observations increase the confidence

interval will narrow. It is not possible to predict detection levels *a priori* since observation numbers are not controlled by the observer.

Data are entered and stored on 9-track, 1600 bpi magnetic tape according to established quality assurance procedures. Field procedures are identified in the quality assurance manual.

c. Experimental Design and Data Analyses - The avifauna data are presented as species composition and relative abundance (individuals of a bird species per total number of birds observed) for sagebrush and pinyon-juniper habitats in the control and treatment areas. For each year of the program and for each habitat type, species found in both the control and treatment area are ranked according to their relative abundance; Spearman's Rank Order Correlation Coefficient is then calculated to determine the degree of independence between the control and treatment data. Coefficients of rank correlation are compared between years to determine if the relative abundance of avifauna species has changed as site development progresses.

The data will be used to test the hypothesis:

H_0: There is no significant difference in the rankings of the relative abundance of avifauna species on control and treatment areas within each habitat type when rankings are compared between years.

H_0: There is no significant difference in the rankings of the relative abundance of avifauna species between transects within a habitat type within a control or treatment area within the same year.

Interpretations of the bird data are constrained in several ways. The coefficients of rank correlation provide an indication of the degree of independence of the relative abundance rankings of species in the control and treatment areas; there is no obvious rationale to explain the degree of independence other than the expectation that similar habitats should have similar avifauna populations.

Tests of the null hypothesis indicate whether or not there are statistically significant differences in the coefficients of rank correlation between years; if the null hypothesis is rejected it means only that there may have been differences in the relative abundance rankings of avifauna on the control and treatment areas. These differences could be due to natural variation, "treatment effects", or sampling errors (e.g. differences in phenology between identical calendar dates during the two years, sample sizes too small).

If significant differences between locations occur, a detailed analysis of other parameters sampled in the two locations will be initiated. This analysis will indicate if these differences reflect natural fluctuations or are also evident in soil and/or vegetation elements. If it appears that oil shale activities are adversely affecting avifauna population levels, additional bird studies will be initiated.

3. Mule Deer Density

a. Objectives - Mule deer are the most important game species in Colorado in terms of recreational use and money expended by hunters. The Piceance Creek basin mule deer herd is one of the largest migratory mule deer herds in North America. Tract C-a is within Colorado Division of Wildlife's (CDOW) Game Management Unit 22 (Piceance).

Moderate numbers of mule deer occur on Tract C-a during migration periods, particularly spring, and during mild winters. At other times mule deer are relatively uncommon on the tract. Consideration of the possible effects of Tract C-a oil shale development on mule deer is an integral part of RBOSC's Fish and Wildlife Management Plan.

The objectives of RBOSC's mule deer monitoring program are to obtain an index of mule deer density in a 9 x 9 mile (81 sq. mile) study area centered on Tract C-a (Figure 4-2), to compare indices of mule deer density from the study area with those from Game Management Unit 22, and, if possible, to compare differences in mule deer densities within various portions of the study area.

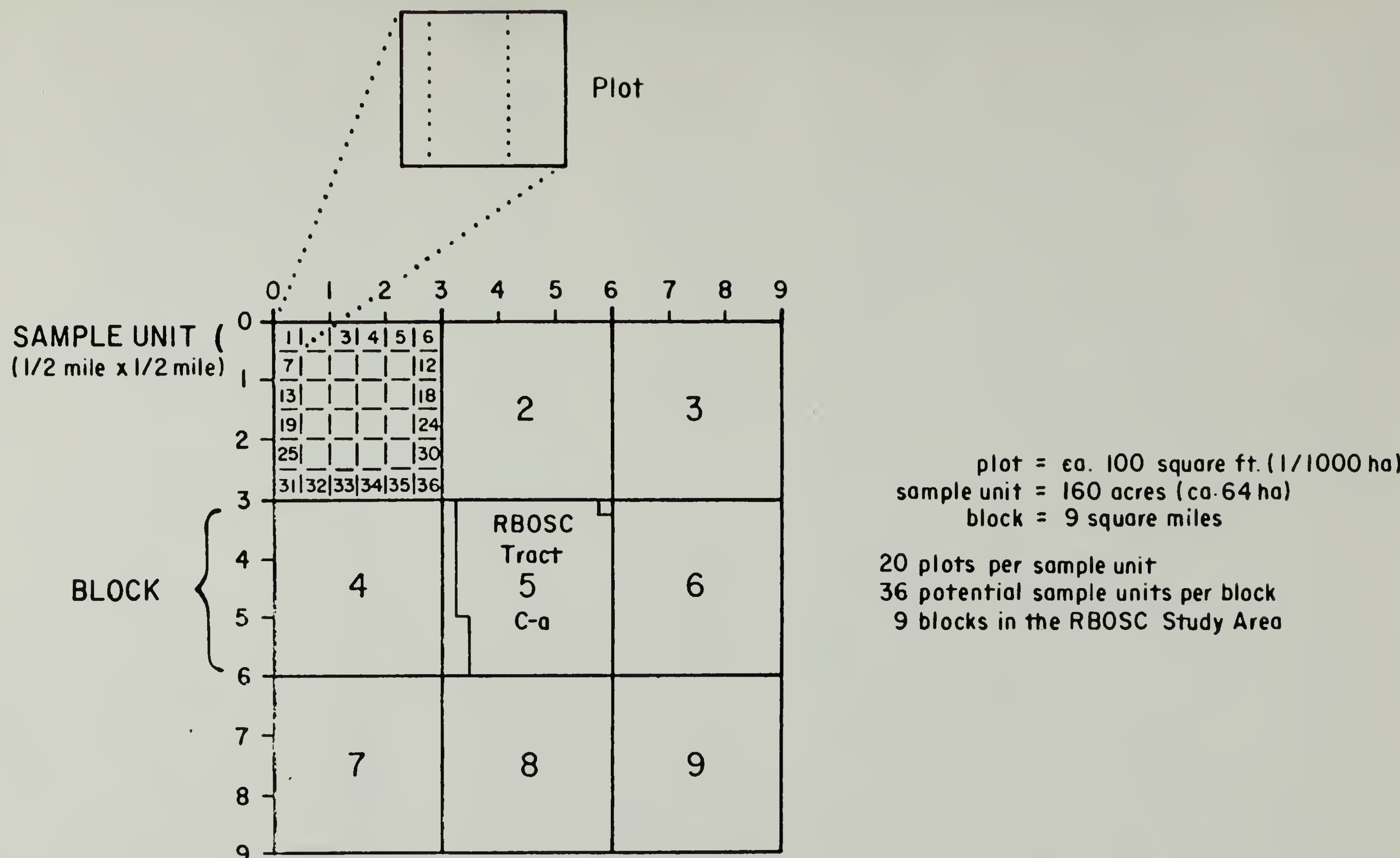


Figure 4-2

Study Area for Mule Deer Pellet-Group Counts

b. <u>Methods</u> - Tract C-a is in the center of a 9x9 mile (81 sq mi) study area which is divided into 9 blocks (3 x 3 miles or 9 sq mi each). Seven quarter sections (160 acres, 64 ha) have been randomly selected from each block.

Twenty plots or 2 transects of 10 plots each (107.64 sq ft (1/1000 ha) each) are randomly spaced within each of 63 randomly selected quarter section sampling units (7 units in each of the 9 blocks) (Figure 4-2). The boundary of each plot is determined by placing one end of a 5.8 foot (1.78 m) long chain on a center stake and walking around the stake with the opposite end of the chain pulled taut. Pellet-groups found within the circular plots are counted; to qualify as a group, six or more pellets must be present. Groups on the boundary of a plot are counted if one-half or more of the total number of pellets are within the plot. Sampling plots used during monitoring are marked with a numbered metal stake at the center of each plot.

Pellet-group counts are made twice a year, in the spring (May) and in the fall (September), to determine the number of pellet groups deposited in the summer and during the migration and wintering periods (Table 4-1). All pellet groups are removed from the plots as they are counted.

Data are entered and stored on 9-track, 1600 bpi magnetic tape and all data analyses are performed by computer. Documented data control and field procedures are followed.

c. <u>Experimental design and data analysis</u> - Assessments of potential impacts of development require knowledge of deer distribution and abundance before mining or enhancement activities begin. To this end the following hypotheses will be tested.

H_0: Mule deer density estimates for RBOSC's 81 sq mi study area are not significantly different from those for Game Mangement Unit 22 (per unit area).

H_0: Mule deer numbers and distribution within the 81 sq mi study area are not significantly different before and during modular oil shale development activities.

A stratified random sampling program (Cochran 1963) was employed to estimate mule deer density from pellet group counts. For each 9 square mile block, 7 of the 36 quarter square-mile sample units were randomly selected then subsampled by two transects, one quarter mile apart, each containing 10 plots, 107.64 ft^2 (1/1000 hectare) in size, spaced at 0.05 mile intervals south to north. The principal reasons for stratification are outlined by Cochran (1963). In the following discussion, the notation employed in Cochran (1963) will be followed.

In order to determine confidence limits for the population mean density of pellet groups, an approximate method (Satterthwaite 1946) of assigning an effective number of degrees of freedom n_e to $v(\bar{y}_{st})$ is:

Define terms of the equations

$$n_e = \frac{(g_h s_h^2)^2}{\frac{g_h^2 s_h^4}{n_h - 1}}, \qquad \text{where } g_h = \frac{N_h(N_h - n_h)}{n_h}$$

Employing the above formulas the effective number of degrees of freedom is 31.

These confidence limits estimate the mean density of mule deer pellet groups within ±14 percent of the mean 90 percent of the time.

Mule deer density estimates are calculated from pellet-group data. The number of pellet groups per unit area, days of use by deer, and deer per acre in the study area are being determined as described by Overton (1971). These analyses provide an estimate of the number of deer per square mile in the 81 sq mi study area. This estimate is compared with the CDOW estimate for Game Management Unit 22. If pellet-group data are available from CDOW, mean density estimates for Unit 22 and the 81 sq mi study area will be compared statistically (i.e., t-test) (Seber 1973).

If data collected from each block are adequate (sufficient number of pellet groups), differences in deer densities between blocks will be compared by the following ANOVA.

	Source of Variation	Degrees of Freedom	F-Test
A.	Phase a = ~~3~~ 2	a-1 = ~~2~~ 1	A/H
B.	Seasons b = 2	b-1 = 1	B/H
C.	Location c = 9	c-1 = 8	C/H
D.	Phase x Seasons	(a-1)(b-1) = 2	D/H
E.	Season x Location	(b-1)(c-1) = 8	E/H
F.	Phase x Location	(a-1)(c-1) = 16	F/H
G.	Phase x Season x Location	(a-1)(b-1)(c-1) = 16	G/H
H.	Error (n = 7)	abc(n-1) =324	
	Total	nabc-1 =377	

This three-way ANOVA is used to determine differences between phases (main effect A), between seasons (main effect B) and differences among locations (main effect C) which might indicate differences in deer distribution. First order interactions include phase and season (D), season and location (E) and phase and location (F) differences. The second order interaction determines deer density by phase, season and location. If significant differences in the interactions and main effects terms occur, a Duncan's multiple range test will be conducted to determine the sources of variation.

The feasibility of making statistical comparisons of pellet-group data from the nine blocks depends primarily on the number of plots sampled and the frequency and distribution of pellet groups counted. CDOW is currently conducting experimental pellet-group count studies for mule deer in the Piceance Creek basin. Results of the pellet counts and other CDOW mule deer studies are being incorporated into RBOSC studies on a regular basis to the extent possible. CDOW studies may provide information useful in determining sample size (i.e., number of sample units and number of plots per sample unit) for the RBOSC studies.

4. Mule Deer Road Kill Study

The Piceance Creek Basin is the current center of a great deal of energy development activity including oil shale and natural gas. This increased activity has resulted in increased traffic flows across mule deer migration routes. The CDOW is interested in obtaining data relative to the mortality of mule deer as a result of deer-vehicle collisions.

a. Objectives - The objective of this program is to provide data on mule deer mortality along County Road 24 from Piceance Creek to Tract C-a for compilation and use by the CDOW.

b. Method - Mule deer mortality data are collected three times per week, along a 13-mile stretch of County Road 24 from Piceance Creek to Tract C-a during prime migration periods (September to March). Data are recorded on a field log by the RBOSC Field Biologist each sample day.

At the initial observance of a new carcass the location is marked on a map using a number representing the sequential kill count of the month (e.g. 4 meaning the 4th new carcass sighted that month). Duplication of counts is avoided by conspicuously marking the carcass with a patch of brightly colored spray paint or by marking the area with flagging. Marked carcasses will be omitted from subsequent counts. A new map is used each month, and monthly kill counts as marked on the map plus supplementary data are forwarded to the CDOW (through the DCM/OS ~~Area Oil Shale Supervisor~~) on a monthly basis. Maps are sequentially numbered for identification and dated. This information is duplicated on the field log.

Data recorded for each new carcass sighted include:

- Date of observation
- Location (marked on map)
- Kill count number for the month (marked on map and field log).
- Time of day (a.m. or p.m.)
- Sex (male, female, undetermined)
- Age Group (Adult, Immature)
- Comments

These data are recorded for each carcass only once, at the initial observation.

c. Experimental Design and Data Analysis - The program is designed to provide supplemental information to RBOSC for evaluation of effects of development on the mule deer herd and to assist the CDOW in compiling regional information on mule deer in the basin. The data are reported in semi-annual reports, but no attempt is made to quantify the data nor to test a stated null hypothesis.

5. Feral Horse Abundance

a. Objectives - Feral horses occur on and in the vicinity of Tract C-a. These horses are protected under Federal law and are under the jurisdiction of the BLM. Feral horses compete with cattle and, to a lesser extent, with mule deer for available forage. The objective of feral horse monitoring studies is to provide qualitative information concerning the status of feral horses in the RBOSC study area.

b. Methods - Feral horses on Tract C-a and within three miles of the tract boundary (i.e., same study area as mule deer) are counted annually in January. Transects are flown with a helicopter, and the location and number of horses observed are recorded. The aerial census data are supplemented by general observations (number; activity when observed e.g., watering, feeding) of horses recorded during other terrestrial ecology studies in May and September (Table 4-1).

c. Experimental design and data analyses - The total number of horses seen in the study area is compared with the number estimated to be in the area by state and federal agencies. This information provides a qualitative description of the status of feral horses in the study area.

6. Threatened and Endangered Species and General Wildlife Survey

Baseline and interim monitoring studies indicated that Tract C-a does not provide critical habitat for any state or Federally endangered species. During baseline studies, greater sandhill cranes were observed on 84 Mesa, at the

Stake Springs impoundment and east of the 84 Ranch. A whooping crane was sighted east of 84 Ranch. Because RBOSC development activities are not expected to affect the areas where sightings have been made, a specific program for endangered species has not been included in the current monitoring program.

The RBOSC field biologist conducts studies on and near Tract C-a during all parts of the year. Observations of any threatened or endangered species will be reported to the ~~A~~OSO and appropriate studies will be initiated as determined by RBOSC and the ~~A~~OSO. A field log is kept by the field biologist. Should unusual trends or significant changes in animal behavior or population parameters be noted the ~~A~~OSO will be notified. RBOSC will work with the ~~A~~OSO biologists to explain the reasons for such changes.

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5.0 AQUATIC STUDIES

As part of the two-year Environmental Baseline Monitoring Program, data on the aquatic ecosystem were collected at 35 separate sampling stations representative of aquatic habitats found in the vicinity. These stations were located on Tract C-a and downstream of the tract on Corral Gulch, Stake Springs Draw, Yellow Creek and the White River. The studies were designed to inventory the aquatic biota and to determine the baseline characteristics of the aquatic resources. Aquatic biological studies were conducted in conjunction with limited physicochemical studies of surface water. Species composition, relative abundance, and distribution of phytoplankton, zooplankton, macrophytes, periphyton, benthos and fish were determined. In addition, productivity studies were conducted for periphyton and data on age and growth, condition and reproduction were determined for fish collected from the White River and Yellow Creek. Extensive physical and chemical data on ground and surface water were collected concurrently as a part of the geotechnical and hydrological investigations.

The analysis of the aquatic baseline data (RBOSP 1977a) indicated that periphyton are the major primary producers in the study area and that benthic invertebrates are the primary aquatic consumers. Fish occur only in lower Yellow Creek and the White River. Other streams in the study area have intermittent or ephemeral flow and do not support fish populations. Analysis of these baseline data led to the selection of important ("indicator") parameters for inclusion in the development monitoring program. The MDP aquatic monitoring program currently being conducted on Tract C-a is designed to monitor potential impacts of MIS oil shale development. This plan was developed after thorough analysis of environmental baseline data collected from October 1974 through September 1976.

An important step in the development of the MDP aquatic monitoring program was the identification of those aquatic factors likely to be impacted by development. This was done through the use of a qualitative "cause-effect" matrix analysis (RBOSC 1977b) and through the use of a "measurability" matrix (RBOSC 1977b) which identified the measurability of a parameter, based upon experience

with the analysis of RBOSC baseline data, expert judgment and the current state-of-the-art biometrics.

Modifications to the development plan and an increased understanding of the aquatic ecosystems in the area have led to revisions to the aquatic monitoring whenever appropriate. The revised monitoring program described herein reflects an assessment of combined impacts that may result from the construction and operation of the Lurgi demonstration facility and the ongoing MIS activities.

5.1 ABIOTIC MONITORING

A. Physical Measurements

1. Objectives

The objectives of taking physical measurements during the aquatic monitoring studies are to characterize the physical habitat at each sampling site and to relate habitat data to chemical and biological conditions observed at each site. These objectives are consistent with Section 1(c)1 of the Tract C-a lease.

2. Methods

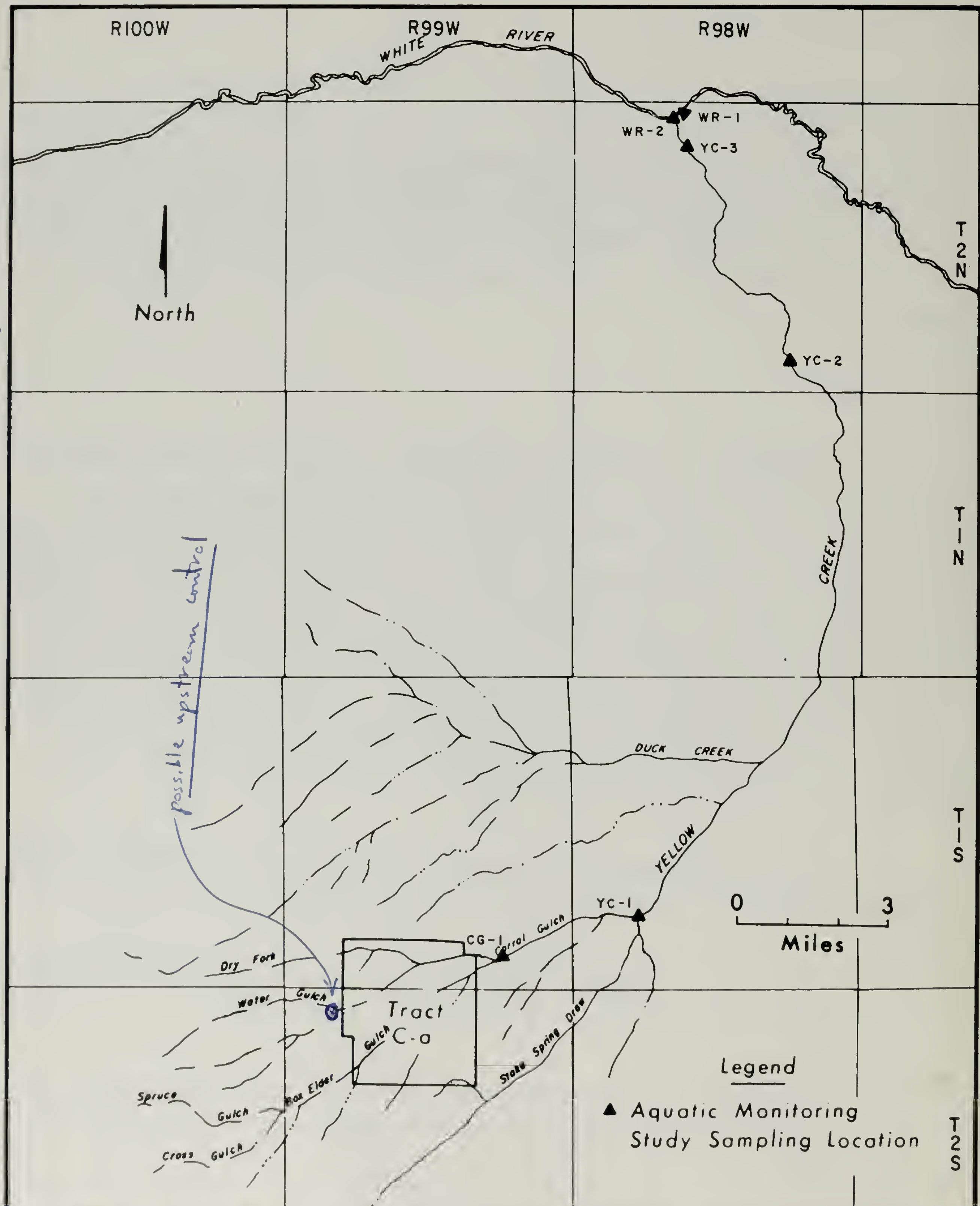
a. Parameters - The physical parameters selected for these monitoring studies are those which are likely to be influenced by development (e.g., increased siltation and turbidity, changes in flows) and which have been shown, through analysis of baseline data, to be of importance to the aquatic community on and near Tract C-a. The parameters include: stream velocity, turbidity, dissolved oxygen, pH, alkalinity, specific conductance, water temperature, depth, width and stream substrate composition. In addition to this program, a more extensive program for the collection and analysis of physical data, which will be used to document changes from baseline, is described in the Hydrology Monitoring Program (Section 6).

b. Monitoring locations - The sampling locations for the RBOSC aquatic monitoring program are shown in Figure 5-1 and include:

- Station CG-1 (formerly Station 13) at the U.S.G.S. gaging station in Corral Gulch (east). CG-2 ? (pg 78)

- Station YC-1 (formerly Station 14) on Yellow Creek downstream (approximately 100 m) of the confluence of Stake Springs Draw and Corral Gulch.

upstream control ?
potential use of SPG-3, SPG-4, SPG-20 (pg 125)



off-tract property

Figure 5-1
Locations of Aquatic Ecology MDP Sampling Sites

- Station YC-2 (a new station) at the road crossing 6 miles from the confluence of White River and Yellow Creek (15.8 miles along the Yellow Creek road from 84 Ranch).

- Station YC-3 (formerly Station 21) at the U.S.G.S. gaging station on Yellow Creek (approximately 0.25 miles from the confluence of Yellow Creek and White River).

- Station WR-1 (formerly Station 27) upstream of the confluence of Yellow Creek and White River.

- Station WR-2 (formerly Station 29) downstream of the confluence of Yellow Creek and the White River.

These stations were chosen because they are representative of the primary habitat types found in the area and because they are in a location that will provide for early detection of any impacts that may result from oil shale development. The stations on Corral Gulch and Yellow Creek will monitor the effects of tract activities on the aquatic community downstream from the tract. Station WR-2 will monitor potential effects of tract activities on the aquatic community in the White River. Station WR-1 on the White River will serve as an upstream control.

c. Monitoring Frequency and Schedule - Sampling is conducted three times a year to allow comparison of seasonal changes. This is a reduction from the sampling frequency in the past which was six times per year. This reduction in sampling frequency is based upon the results of a three-way Model I Analysis of Variance with unequal but proportional subclasses (Sokal and Rohlf 1978). These analyses indicated that there was no significant difference within each seasonal grouping of April and May, and June, July and August for the periphyton and benthos diversity and abundance indices. Furthermore there was a significant difference ($P > 0.05$) between the grouped seasons of April and May; June, July and August; and October for biotic data. Sampling will be carried out during the last two weeks of the month in April, July and October (Table 5-1).

Table 5-1. MDP Aquatic Ecology Studies Monitoring Program Schedule

Parameter	Location	Frequency
	Abiotic	
Physical Measurements		
Stream Velocity Turbidity Dissolved Oxygen pH Specific Conductance Water Temperature Depth Width Stream Substrate	Stations CG 1 & 2, not shown on Fig 5-1 YC-1, YC-2 and YC-3 WR-1 and WR-2 (See Figure 5-1)	3 times/year (April, July, Oct.)
Water Quality Measurements ~~(White River)~~		
Boron Calcium Chloride Fluoride Magnesium Nitrate Orthophosphate Potassium Total Phosphate Silica Sulfate Sodium Alkalinity Total dissolved solids Bicarbonate	Stations CG-1 YC-1, YC-2 and YC-3 WR-1 and WR-2 (See Figure 5-1)	3 times/year (April, July, Oct.) also once/year (basic and trace water quality analyses pg 107-109)
	Biotic	
Periphyton	Stations CG-1 YC-1, YC-2 and YC-3 WR-1 and WR-2 (See Figure 6) ?	3 times/year (April, July, Oct.)
Benthos	~~Stations CG-1~~ YC-1, YC-2 and YC-3 WR-1 and WR-2 (See Figure 5-1)	3 times/year (April, July, Oct.)

d. Data Collection Methods - Physical characteristics of the streams are measured concurrently with the collection of chemical and biological samples. Stream velocity is measured with a Gurley flowmeter or equivalent. The stream substrate is visually classified at each station. The turbidity of each sample is determined with a Hach Photometric Turbidimeter or equivalent.

Other parameters (and methods of measurement) which are determined in the field include pH (portable meter), specific conductance (portable meter), water temperature (thermistor or equivalent), dissolved oxygen (portable meter), depth, width and total alkalinity (colorimetric; APHA, 1976).

e. Data Handling and Quality Assurance - Data are entered and stored on nine track, 1600 bpi magnetic tape. Quality control procedures as defined by the Quality Assurance Program are implemented. Field and laboratory work is conducted according to specific work instructions which conform to accepted methods for collection and handling of data. These work instructions are contained in program-specific field and laboratory manuals and/or the scope of work. All field and laboratory instruments are calibrated according to factory or otherwise accepted standards as described in the RBOSC Quality Assurance program manuals. Field procedures are periodically audited by the RBOSC Quality Control Officer and AOSO staff.

3. Experimental Design

Physical data collected as part of the aquatic studies program are used in concert with the chemical and biological data to characterize the aquatic habitat and define changes which may occur. Comparison of changes in physical conditions will be made using a three-way Model I Analysis of Variance. The following hypotheses will be tested.

H_0: There are no significant differences in the physical measurements between the baseline and the reporting period.

H_0: There are no significant differences in the physical measurements between sampling stations.

H_o: There are no significant differences in the physical measurements between seasons.

The Analysis of Variance table in Table 5-2 depicts the design to be used for the analysis of physical measurements and the water quality parameters. If there is a significant difference between the variances of the interaction terms and main effects, a Duncan's Multiple Range Test will be run to check for differences in the means.

B. Water Quality Measurements

1. Objectives

The objectives of including water quality studies in the aquatic studies program are to monitor those chemical constituents which the analysis of RBOSC baseline data (RBOSP 1977a) have shown to contribute most to the natural variability in water quality. Analysis of the data will be conducted to monitor year to year, seasonal, and station differences, and to monitor natural and development-related variation. These objectives are consistent with Section 1(c)1 of the Tract C-a lease.

2. Methods

Chemical parameters for water quality studies were chosen as a result of statistical analysis of baseline water quality data. Methods of statistical analysis for baseline data included: factor analysis, cluster analysis, regression, and correlation analysis as discussed in the Final Environmental Baseline Report (RBOSP 1977a).

From the analysis of baseline water quality data, it appears that the 14 parameters listed in Table 5-3 will serve as indicators of overall water quality and provide sufficient indication of change to meet the stated objectives. Observations of unexpected changes in water quality will be carefully evaluated and appropriate sampling and analytical techniques will be incorporated in cooperation with the ~~Area~~ Oil Shale Office.

Table 5-2. Three-way Analysis of Variance (Model I) Design for Physical Measurement and Water Quality Analyses.

This is a fixed effects model and factors should be tested against error.

	Source	df	F-Test	Expected MS. (Model 1)
A.	Years (Baseline & reporting period)	a-1	A/H	$\sigma^2 + \frac{bc}{a-1} \sum^{a} \alpha^2$
B.	Stations (6 stations)	b-1	B/H	$\sigma^2 + \frac{ac}{b-1} \sum^{b} \beta^2$
C.	Seasons (Spring, Summer, Fall)	c-1	C/H	$\sigma^2 + \frac{ab}{c-1} \sum^{c} \gamma^2$
D.	A x B Interaction (Years x Stations)	(a-1)(b-1)	D/$\cancel{G}$ H	$\sigma^2 + \frac{c}{(a-1)(b-1)} \sum^{ab} (\alpha\beta)^2$
E.	A x C Interaction (Years x Seasons)	(a-1)(c-1)	E/$\cancel{G}$ H	$\sigma^2 + \frac{b}{(a-1)(c-1)} \sum^{ac} (\alpha\gamma)^2$
F.	B x C Interaction (Stations x Seasons)	(b-1)(c-1)	F/$\cancel{G}$ H	$\sigma^2 + \frac{c}{(b-1)(c-1)} \sum^{bc} (\beta\gamma)^2$
G.	A x B x C Interaction (Year x Station x Season)	(a-1)(b-1)(c-1)	G/H	$\sigma^2 + \frac{1}{(a-1)(b-1)(c-1)} \sum^{abc} (\alpha\beta\gamma)^2$
H.	Error Term	abc(n-1)		σ^2
	Total	abcn-1		

Table 5-3. RBOSC Water Quality Program

Parameter	Detection Limits		Methodology	Sample Preservation
Alkalinity (total)	2.0	mg/l	Colorimetric	Refrigeration
Boron	0.2	mg/l	APHA[1/] 405A	None Required
Calcium	0.02	mg/l	Atomic Absorption	HCl*
Chloride	0.4	mg/l	Potentiometric	None Required
Fluoride	0.02	mg/l	Electrode	None Required
Magnesium	0.005	mg/l	Atomic Absorption	HCl
Nitrate	0.01	mg/l	APHA[1/] 419C	$HgCl_2$
Orthophosphate	0.01	mg/l	EPA[2/]	$HgCl_2$
Potassium	0.01	mg/l	Atomic Absorption	HCl
Total Phosphate	0.01	mg/l	EPA[2/]	$HgCl_2$
Silica	0.04	mg/l	APHA[1/]	HCl
Sulfate	1.0	mg/l	APHA[1/] 427C	Refrigeration
Sodium	0.01	mg/l	Atomic Absorption	None Required
Total Dissolved Solids	1	mg/l	Filtration & Evaporation	None Required

1/ American Public Health Association (APHA)

2/ Environmental Protection Agency (EPA)

* HCl is an optional preservative

Note: Samples will be retained for three months following submission of the year-end report.

a. Constituents - Constituents to be included in the water quality monitoring program are: boron, calcium, chloride, fluoride, magnesium, nitrate, orthophosphate, potassium, total phosphate, silica, sulfate, sodium, total alkalinity, total dissolved solids and bicarbonate.

b. Monitoring Locations - Six sampling sites (Figure 5-1) are included in the aquatic water quality monitoring program. These stations are the same as those used to monitor physical parameters.

c. Monitoring Frequency and Schedule - Sampling is conducted three times a year to allow for seasonal comparison between monitoring and baseline data. Sampling is scheduled for April, July and October.

d. Sample Collection, Analysis and Quality Assurance - Table 5-3 lists the analytical methods, limits of detection and methods of sample preservation for the water quality program. Replicate samples (2) are collected at each location. Samples are preserved (if appropriate) and shipped to the laboratory within 24 hours of collection. Shipping procedures, laboratory long-in and verification and reporting procedures follow those described in the Quality Assurance Program.

e. Data Handling - Data are entered and stored on nine track, 1600 bpi magnetic tape according to procedures outlined in the Quality Assurance Program.

3. Experimental Design and Data Analysis

In fulfilling the objectives of these studies, three hypotheses will be tested using a three-way Model 1 Analysis of Variance. If there is a significant difference in the variances between the interactions and the main effects then a Duncan's Multiple Range Test will be used to examine differences in means for each of the water quality parameters. The hypotheses to be tested are as follows:

H_0: There is no significant difference in the water quality between the baseline and development monitoring periods at the same location.

H_0: There is no significant difference in the seasonal water quality between baseline and report period.

H_0: There is no significant difference in the water quality between control and treatment sample sites.

For the experimental design, WR-1 will serve as a control site and WR-2 will serve as a treatment site. Baseline data will also be defined as a control, with report period data serving as the treatment.

5.2 BIOTIC MONITORING

As indicated in the introduction to the Aquatic Studies program, selection of biological parameters for inclusion in the RBOSC MDP monitoring program was based upon a comprehensive analysis of the aquatic baseline data and upon an assessment of potential impacts of the Lurgi and MIS facilities on the aquatic systems.

A. Periphyton

1. Objectives

The objectives of the periphyton studies are to monitor biomass, species composition, relative abundance and diversity of the periphyton community, in order to identify and document any changes (both natural and tract related) in these characteristics which may effect the aquatic system in the Tract C-a area.

The periphyton data from these studies will be compared to the physical and chemical conditions, and to the condition of the benthos population, to provide an overall assessment of the changes in the aquatic habitats near Tract C-a. The objectives of these studies are consistent with the overall objectives of the environmental program and Section 1(c)1 of the Tract C-a lease.

2. Methods

a. Parameters - The periphyton population characteristics selected for monitoring include species composition, relative abundance, biomass and species diversity. These characteristics correspond to parameters studied during baseline and will provide data suitable for comparison with baseline data.

b. Monitoring Locations - The monitoring locations identified in Section 5.1 are utilized for RBOSC periphyton studies. Station WR-1 and baseline data will serve as "controls". Station WR-2 and development period data will serve as "treatments".

c. Monitoring Frequency and Schedule - Samples are collected three times a year (April, July, October) to allow for seasonal comparison of monitoring and baseline data.

d. Sample Collection, Analysis and Quality Assurance - Eight replicate samples of periphyton are collected at all six sample sites--four for relative abundance, and four for biomass. Sample size was determined after an inspection of the baseline and MDP data. Equal numbers of samples are collected at each station to provide for a balanced statistical design.

Periphyton are collected from areas of equivalent flow, if possible. Rocks that have relatively flat upper surfaces and are positioned at mid-depth in riffles are selected for the collection of periphyton samples. The rocks are removed carefully from the streams and each replicate taken by removing the periphyton from a 50 cm^2 area with a toothbrush and water (Northern States Power Co. 1974). The resultant suspension of material is preserved in 5 percent neutralized formalin.

In the laboratory, the preserved periphyton samples are diluted to a constant volume, an aliquot removed, centrifuged and washed with distilled water. The samples are then stained and dehydrated in the centrifuge, using successive spinnings and decantings. A number of drops of the final xylene-periphyton suspension are placed on a microscope slide with Hyrax, heated gently and covered with an ultra-thin coverglass. The final mounts are retained in the permanent voucher collection. See Aquatic Annual Report for methods (RBOSP 1976).

Periphyton are studied using an oil immersion microscope. All organisms appearing in one randomly chosen transect at 1000X are counted. The whole slide is then surveyed at 100X to identify and enumerate larger rare species. Counts are expressed as cells per unit area. These data are used to compute relative abundance and species diversity. Slides are retained in a voucher collection as per the Quality Assurance procedures. The contract laboratory maintains strict quality control procedures. All quality assurance documentation is forwarded to RBOSC annually. Audits of contractor facilities are conducted periodically by RBOSC personnel.

Biomass determinations are made by weighing the samples dried at a constant temperature of 105°C followed by ashing at 550°C and reweighing (Vollenweider 1969). The calculated ash-free dry weights are estimates of the organic weight or biomass of the periphyton.

e. Data Handling - Data are entered and stored on nine track, 1600 bpi magnetic tape according to documented quality assurance procedures.

3. Experimental Design and Data Analysis

In fulfilling the objectives of these studies, the following hypotheses will be tested:

H_0: There is no significant difference in the relative abundance of periphyton between the baseline and development monitoring periods in similar habitats.

H_0: There is no significant difference in periphyton diversity between baseline and development monitoring periods in similar habitats.

H_0: There is no significant difference in the biomass of periphyton between the baseline and development monitoring periods in similar habitats.

Hypotheses for biomass and diversity are tested by using analysis of variance techniques (Table 5-4). For relative abundance, the hypotheses presented above will be evaluated by utilizing the Spearmans Rank Order Correlation nonparametric technique.

Species composition of the periphyton community is monitored to determine if trends or shifts from sensitive to tolerant species occur. This will be done by comparing pre-development and development phase populations of species which have known ecological spectra. Changes in species composition may be presented in a non-statistical hypothesis as follows:

Table 5-4. Analysis of Variance for Biomass of Periphyton

	Source	df	F Test
A.	Year (baseline & report period)	a-1	$\frac{A}{H}$
B.	Season (Spring, Summer, Fall)	b-1	$\frac{B}{H}$
C.	Station (six stations)	c-1	$\frac{C}{H}$
D.	A x B Interaction (Year x Season)	(a-1)(b-1)	$\frac{D}{H}$
E.	A x C Interaction (Year x Station)	(a-1)(c-1)	$\frac{E}{H}$
F.	B x C Interaction (Season x Station)	(b-1)(c-1)	$\frac{F}{H}$
G.	A x B x C Interaction (Year x Season x Station)	(a-1)(b-1)(c-1)	$\frac{G}{H}$
H.	Error	abc(n-1)	
	Total	abcn-1	

There is no major change in periphyton species composition between baseline and development monitoring periods at the same locations.

In addition to the above, analyses of pre- and post-construction communities will be made using an index of similarity which will provide a quantification (percent) of the degree of difference (or similarity) among communities for comparable sampling periods. These computations will be made using densities of each taxon (Owen 1973).

Diversity indices will be used as a final means of comparing pre- and post-construction phase periphyton communities. Information theory and diversity indices (Brillovin 1956, Lloyd et al. 1968, EPA 1973), as well as evenness and richness (Pielou 1969, Margalef 1969) will be computed. While these indices do not take into account species composition, they do provide useful measures of community structure.

In summary, the pre- and post-construction periphyton communities will be compared using several measurements of community structure and density. Statistical analyses will be employed to detect changes in relative abundance and diversity among sites and between baseline and the reporting period. If significant changes are detected, additional studies will be initiated as necessary to investigate the cause and effect relationship of the changes.

B. Benthos

1. Objectives

The objectives of the benthic invertebrate studies are to monitor relative abundance, species composition and diversity of the benthic communities, in order to identify and document changes (both natural and project related) in these characteristics which may effect the aquatic system in the Tract C-a area.

The benthos data from these studies will be compared to the physical and chemical conditions and the periphyton population to provide an overall assessment

of the changes in the aquatic habitats on and near Tract C-a. The objectives of these studies are consistent with Section 1(C)1 of the Tract C-a lease.

2. Methods

a. Parameters - The benthos population characteristics selected for monitoring include: species composition, relative abundance and species diversity.

b. Monitoring Locations - Samples of the benthic invertebrate community will be collected at the same six monitoring locations as described in Section 5.1 and depicted on Figure 5-1.

c. Monitoring Frequency and Schedule - Samples will be collected three times a year to allow for seasonal comparison of monitoring and baseline data. Monitoring is conducted during April, July and October. Preliminary testing indicated that this seasonal grouping will adequately account for changes in the benthic community.

d. Sample Collection, Analysis and Quality Assurance - Baseline data on benthic invertebrates were used to calculate the sample size required for statistical accuracy for each type of habitat. These calculations indicated that only semi-quantitative benthic sampling can be accomplished within the limits of time and habitat available near Tract C-a.

At each sampling site, 3 replicate samples are collected with a modified Hess sampler. During the RBOSP aquatic baseline studies, this sampler was proven effective in rubble and gravel substrates. The modified Hess sampler has been previously described in RBOSC workscopes as a modified Surber sampler. In reality, the modified Hess sampler used throughout the two years of aquatic baseline studies, during interim monitoring studies and during the current development monitoring studies is a modification of the original Surber square-foot sampler similar to that described by Waters and Knapp (1961). The modified Hess sampler (FD8-522 cm^2) is a lightweight, shallow-water benthos sampler. It is cylindrical or elliptical in shape and consists of a metal

frame with #30 mesh (0.6 mm aperature) side curtains. The side screening prevents the capture of drifting organisms.

After collection, benthos samples are washed using a U.S. Standard No. 30 sieve, and are preserved with neutralized 10 percent formalin.

Standardized methods of sample processing and analysis are utilized in the laboratory and documented in the Quality Assurance program. Samples are first rinsed in 20 cm diameter No. 60 sieves with light-pressure fine spray to remove specimens from rocks and any fine sediments. The samples are then hand-sorted under dissecting microscopes at 6X magnification. Organisms are removed from the sample with forceps, eye droppers and probes to petri dishes or watch-glasses containing water. Samples are systematically searched, and the examined portions are pushed aside. Unidentified material are also removed along with the organisms and examined under dissecting microscopes. The organisms are stored in plastic capsules in 70 percent ethanol.

Chironomidae and Oligocheata are cleared in xylene and then mounted on permanent slides in Canada balsam. Only complete oligochaetes with intact anterior portions are enumerated.

With few exceptions, benthic organisms are generally identifiable to genus without special preparation. Organisms are identified to the lowest taxon possible. Individuals are usually identified under the dissecting microscope or on temporary slides (under water) under a compound microscope.

Only those individuals which are living at the time of collection, as indicated by presence of fleshy tissue, are enumerated for the purpose of estimating populations. Empty mollusc shells, exuvia, reproductive structures, etc. are retained as aids in identification and for compilation of qualitative species lists, but are not used to estimate population densities. A special reference or voucher collection is maintained apart from other specimens. Quality Assurance audits of the contract laboratory are conducted periodically without prior warning by RBOSC's quality control officer and/or quality assurance supervisor to ensure quality data. Audit reports and corrective action memoranda are filed in the Quality Assurance file.

Should major changes be detected in the benthos populations under study, additional studies will be initiated to determine the source of the change.

e. Data Handling - Data are entered and stored on nine track, 1600 bpi magnetic tape according to documented quality assurance procedures.

3. Experimental Design

In fulfilling the objectives of these studies, the following hypotheses will be tested:

H_o: There is no significant difference in the relative abundance of benthic macroinvertebrates between the baseline and development periods at similar locations.

H_o: There is no significant difference in the species diversity of benthos between the baseline and development periods at similar locations.

H_o: There is no significant difference in species diversity of benthos between the control and treatment stations WR-1 and WR-2.

H_o: There is no significant difference in the relative abundance of benthos between the control and treatment stations of WR-1 and WR-2.

For relative abundance, the above hypotheses will be tested utilizing an index of similarity and Spearman Rank Correlation analyses. The hypotheses for diversity will be tested by utilizing a two-way analysis of variance technique. An index of similarity will also be used in assessing trends in the benthic species composition.

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6.0 HYDROLOGY STUDIES

A. Introduction and Background

This hydrology monitoring program has been organized as follows:

- Introduction, background and a description of the general scope and objectives to be achieved
- A description of the basic program design including the rationale for station selection and classification and constituents to be monitored
- A discussion of the selection of surface water system program elements
- A similar discussion of groundwater system program elements
- Information on analytical procedures and quality control
- Detailed discussions of the experimental design and statistical analyses to be applied to the data
- And finally, identification of specific program elements - stations, locations, frequencies and constituents to be monitored for each impact source

Considerable effort has been devoted to the development and description of the basic program design. This information is intended to outline the logical progression of the program. RBOSC has now accumulated a sizable hydrologic data base (1974-1980). After six years of monitoring and results of numerous statistical analyses, the sampling program has been modified to emphasize the following:

- Integration of all program elements to maximize data utility while taking cost factors into consideration

- Maintenance of maximum flexibility

- Effective and timely impact assessment

- Collection and assimilation of data to refine the definition of the hydrologic regime

In order to accomplish these objectives, RBOSC has developed a scheme for the classification of stations (whether surface or groundwater) according to their spatial likelihood of being impacted by development. These classifications were then further delineated by sampling frequency according to the expected relative length of time over which impacts might be expected to occur. Initial classifications are largely reflective of current knowledge of the hydrogeology of the system. As additional statistical testing is completed, the classification scheme will be further refined.

The selection of constituents to be measured has followed a similar logical progression. This progress has, however, greatly benefited from work performed for the EPA during which a technique for indicator parameter selection was developed. This method (discussed in detail later in this section) has been applied to Tract C-a data in the selection of monitoring constituents.

Further delineation of the basic program design has been accomplished by identifying general surface and groundwater program elements that should be addressed in the specific programs. This step was taken to ensure logical and consistent selection of monitoring elements while at the same time affording maximum flexibility. In other words, once the sampling scheme has been adequately defined, the selection of stations to monitor any given impact source becomes routine. This will ensure that new stations, added to the sampling network as project development expands, will provide data which is amenable to selected statistical treatments and satisfies other stated objectives.

Standardized analytical work is essential to any water quality data base. In order to ensure consistent and reliable analytical data, RBOSC has developed a comprehensive quality control and quality assurance program. A brief discussion of these controls is provided in support of the program.

Central to the refinement of the program is the verification of initial groupings and parameter selection. The experimental design and data base analysis will provide the basis for this refinement. This design is explained in detail as a part of the basic program design for both the surface system and groundwater system programs.

The final step in the development of this monitoring program was the selection of specific stations to monitor potential impacts from each impact source (i.e. MIS site, Lurgi Plant Site, Open Pit, discharges). Selection of specific program elements generally followed the approach described in the basic program design with certain appropriate site specific modifications. These specific details remain flexible and will be modified as appropriate in consideration of project changes, regulatory requirements and data base refinement.

B. General Scope and Objectives

The hydrology monitoring program has been developed to address the following general objectives:

- Integrate surface water, groundwater, springs and operations-related water studies into a unified, comprehensive program.
- Establish a flexible program which will monitor hydrologic impacts of the MIS Program and the Lurgi Demonstration Project separately and in combination.
- Ensure compliance with regulatory stipulations and provide environmental protection.
- Identify development-related impacts on water quality and quantity.
- Develop a cost-effective program for long-term monitoring as well as for short-term requirements.
- Relate surface and groundwaters as to their natural, spatial and temporal variability.

- Define statistical and other approaches for presentation and evaluation of monitoring data.

- Develop program management techniques for timely and effective data handling and for quality assurance.

6.1 BASIC PROGRAM DESIGN

A. Sampling Approach

1. Overview

The hydrology monitoring program has been designed and organized as a comprehensive, unified operation. Monitoring stations to characterize background conditions have been combined with installations directly associated with development activities to provide complete monitoring coverage of potential sources of impact and potentially affected components of the natural hydrologic system. The data analysis and evaluation program will address the potential impacts of the following specific development areas or activities:

- Dewatering/reinjection/discharge program
- MIS modular development area
- Open pit
- Lurgi demonstration plant site development, including spent shale disposal pile

This focus on development activities affects the choice and grouping of sampling stations, sampling frequencies, selection of constituents for monitoring and the data analysis approach used.

Relative to the above development areas, monitoring stations have been grouped generally into control (or unaffected) and treatment (potentially affected) sets. This may be restated as a null hypothesis:

H_0: There is no significant difference between control and treatment station groupings.

Such monitoring networks are designed specifically for detecting changes in the hydrologic regime. Monitoring strategies for regional areas are necessary

for baseline and future, long-term information; however, they cannot be relied upon to provide for early detection of potential pollution problems and timely implementation of environmental control measures. Monitoring sites near potentially affected areas are needed as these will provide early detection of impacts.

Sampling frequencies will be varied relative to distance from the development activity, as a reflection of the influence of such distance on the relative immediacy and potential intensity of effect from the development activity. More frequent sampling is justified for stations near development activities than at upgradient control stations where baseline levels have been adequately defined or for further downgradient stations which, if affected by development, would be affected only after an extended period of time.

Constituents for monitoring have been selected from analysis of background data collected on and near Tract C-a and from expected constituents associated with development activities. For example, constituents which account for most of the baseline variability in water quality are appropriate for sampling at control stations or where only physical changes (e.g., water levels) are anticipated. Constituents associated with potential sources of impact, as indicated by research results and knowledge of mining and land disturbance impacts, will be sampled in areas potentially affected by these sources.

2. Station Classification

Hydrology monitoring stations will be generally classified as follows:

- Type I - control stations not expected to be influenced by a given set of development activities

- Type II - expected to exhibit direct, short-term impacts, should impacts result from development; such stations are located generally downgradient in near field area relative to development

- Type III - expected to exhibit indirect or long-term impacts; should impacts result from development; such stations are located downgradient from development but in far-field areas.

Grouping stations allows for spatial as well as temporal comparison of water quality and physical parameters. Thus "pre- and post-" development levels and the "control vs potentially affected" areas will be compared in future monitoring analyses and reports.

The approach for designating stations groups is to group stations initially using knowledge of the hydrogeologic system and consideration of potential impacts from development. These preliminary groupings, presented in subsequent sections of this scope of work, will then be tested using statistical methods. The results of statistical evaluations will be employed to finalize the groupings as well as to form a basis for identification of impacts and for monitoring review purposes.

3. Selection of Constituents for Monitoring

One important issue in the design of cost-effective ground water quality monitoring is the selection of constituents for monitoring. An evaluation of constituents for monitoring of oil shale operations is summarized in this paper. Assessment of enrichment factors (or concentration change above ambient) and specific indicator constituents is provided. This assessment is part of an on-going program for the U.S. Environmental Protection Agency to develop recommended ground-water procedures for oil shale operations. More complete presentation of the program results is provided by Slawson (1979; 1980a, b).

4. Selection Criteria

Criteria for selection of constituents include the following:

- constituents which are expected to exhibit ~~large~~ significant changes should potentially toxic or hazardous materials leach from materials associated with oil shale operations

- constituents whose presence alone may indicate a ground water impact
- constituents in the above categories for which standard or accepted analytical methods are reasonably available

In addition, it is desirable to build a certain amount of redundancy into the monitoring program by selecting a set of constituents with the above characteristics. This precludes reliance on single indicators and provides a measure of additional assurance in the effectiveness of the monitoring program.

5. Enrichment Factors

Enrichment factors (EF) are calculated from major potential sources of groundwater impact according to the expression:

$$EF = \frac{\text{concentration from potential pollution source}}{\text{concentration in aquifer}}$$

As a demonstration of this approach for selecting monitoring parameters, baseline water quality levels of aquifer systems in the Piceance Creek Basin were compared to constituent concentrations anticipated for retort water and in-situ spent shale leachate. Although this evaluation did not include data on Lurgi spent shale or retort water, the constituents discussed are expected to be similar. The aquifer systems evaluated are alluvial aquifers and two deep bedrock aquifers. Potential impacts from retort water, in-situ spent shale leachate and by interconnection of aquifers of different water quality were considered. Water quality in alluvial and surface stream systems are generally comparable to upper aquifer water quality. Thus, these results may be extended to these surface systems.

The utility of enrichment factor estimates is for identifying the chemical species which indicate the impact of a known source which are likely to be detected in groundwaters. To evaluate this possible monitoring approach, the enrichment factors calculated were categorized as follows:

Category	Enrichment factor range	Relative likelihood of detection of impact
1	> 500	High
2	50 - 500	Moderate
3	10 - 50	Low

The results of this categorization are shown in Table 6-1.

For monitoring in the upper aquifer for the impact from two major sources of impact, consider the enrichment factors shown in Table 6-2.

Table 6-2. Enrichment factors for Potential Sources of Impact to Upper Aquifer

Potential Source of Impact To Upper Aquifer	Water Quality Constituent: Enrichment factor >500	Water Quality Constituent: Enrichment factor 50 - 500
Retort Water These are absolutely unique to retort water	Carbonate Ammonia Phosphate TOC (or DOC) Kjeldahl N Thiosulfate Thiocyanate Arsenic Mercury Vanadium	Conductivity Alkalinity Chloride Bicarbonate Nitrate Cyanide Tetrathionate Chromium Cobalt Selenium Uranium
In-situ Spent Shale Leachate	Carbonate TOC (or DOC) Molybdenum	Conductivity TDS Calcium Magnesium Potassium Sodium Chloride Sulfate Selenium

Need basis for table: what aquifer concentrations used
Type of retort water
In-situ leachate water

Table 6-1. Relative Likelihood of Detecting Migration from Various Oil Shale Development Sources to Upper and Lower Aquifers Based on Estimated Enrichment Factors[a].

Constituent	Lower to Upper Aquifer	In-situ leachate to Upper Aquifer	In-situ leachate to Lower Aquifer	Retort water to Upper Aquifer	Retort water to Lower Aquifer
General water quality measures			Not a low likelihood		Not a low likelihood
Conductivity	---	2	3	2	3
Total dissolved solids	---	2	3	3	---
Alkalinity	---	---	---	2	3
Major inorganic ions					
Calcium	---	2	3	---	---
Magnesium	---	2	2	---	3
Potassium	3	2	---	3	---
Sodium	3	2	3	3	---
Chloride	---	2	2	2	3
Sulfate	---	2	1	---	3
Fluoride	---	3	---	---	---
Bicarbonate	---	---	---	2	---
Carbonate	---	1	2	1	1
Ammonia	3	---	---	1	1
Nitrate	---	---	---	2	2
Phosphate	---	---	---	1	1
Silica	---	---	---	---	3
Organics					
Total organic carbon	---	1	2	1	1
Phenolics	3	---	---	---	---
Kjeldahl nitrogen	---	---	---	1	---
Cyanide	---	---	---	2	2

Table 6-1. (Continued)

Constituent	Lower to Upper Aquifer	In-situ leachate to Upper Aquifer	In-situ leachate to Lower Aquifer	Retort water to Upper Aquifer	Retort water to Lower Aquifer
Sulfur species					
Total sulfur	---	---	---	3	2
Thiosulfate	---	---	---	1	1
Tetrathionate	---	---	---	2	2
Thiocyanate	---	---	---	1	1
Trace elements					
Arsenic	---	3	3	1	1
Barium	---	---	---	---	---
Boron	3	3	---	---	---
Bromide	3	---	---	3	---
Chromium	---	---	2	2	3
Cobalt	---	---	---	2	2
Iron	---	---	---	3	2
Lead	---	---	---	3	3
Mercury	---	---	---	1	1
Molybdenum	---	1	1	3	3
Nickel	---	3	2	3	2
Selenium	---	2	2	2	2
Titanium	---	---	---	3	3
Uranium	---	---	---	2	2
Vanadium	---	3	---	1	1
Zinc	---	3	3	3	3
Radiological					
Gross beta	---	---	---	3	---

a/Enrichment factor (EF) categories: 1 = high likelihood of detection (EF => 500); 2 = moderate likelihood (EF = 50 to 500); 3 = relatively low likelihood (EF = 10 to 50); --- = not applicable.

Examination of Table 6-2 indicates that the constituents shown in Table 6-3 may be unique indicators of impact of retort water or in-situ spent shale leachate on the upper aquifer. A unique indicator is one which is listed in Table 6-2 for one source, but not for the other.

Table 6-3. Possible Unique Indicators for Upper Aquifer Monitoring

Retort Water	In-Situ Spent Shale Leachate
Alkalinity	TDS
Bicarbonate	Calcium
Ammonia	Magnesium
Phosphate	Potassium
Nitrate	Sodium
Kjeldahl N	Sulfate
Thiosulfate	Molybdenum
Thiocyanate	
Tetrathionate	
Cyanide	
Arsenic	
Chromium	
Cobalt	
Mercury	
Uranium	
Vanadium	

Following the same procedure for consideration of monitoring in the lower aquifer, Table 6-4 was extracted from data shown in Table 6-1.

Table 6-4. Enrichment Factors for Potential Sources of Impact to Lower Aquifer

Potential Source of Impact To Lower Aquifer	Water Quality Constituent	
	Enrichment factor > 500	Enrichment factor 50 - 500
Retort water	Carbonate Ammonia Phosphate TOC Thiosulfate Thiocyanate Arsenic Mercury Vanadium	Nitrate Cyanide Total Sulfur Tetrathionate Cobalt Iron Nickel Selenium Uranium
In-Situ Spent Shale Leachate	Molybdenum	Chloride Carbonate TOC Chromium Nickel Selenium

Possible unique indicators were then identified from Table 6-4 as shown in Table 6-5.

Table 6-5. Possible Unique Indicators for Lower Aquifer Monitoring

Retort Water	In-Situ Spent Shale Leachate
Ammonia	Sulfate
Phosphate	Magnesium
Nitrate	Chloride
Tetrathionate	Chromium
Thiosulfate	Molybdenum
Thiocyanate	
Arsenic	
Cobalt	
Iron	
Mercury	
Uranium	
Vanadium	

It is evident from these results that several chemical constituents can be expected to change greatly should groundwaters be impacted by oil shale operations. In addition, several unique indicators are available to differentiate between two important possible impact sources - retort water and in-situ spent shale leachate.

The constituents thus identified as good candidates for routine monitoring programs include most of the major inorganic constituents and common general measures of water quality. Standard analytical methods for these constituents are widely available. It is also interesting to note that statistical analysis of baseline groundwater quality data in the Piceance Basin has indicated that these same constituents account for a major portion of the overall variability in water quality (RBOSP 1977). Thus, such constituents also generally characterize the water quality state of the system.

In summary, analyses of constituents for hydrologic monitoring conclude that major sources of impact on water quality may be effectively monitored by analysis of major inorganic ions, general measures of water quality (pH, total dissolved solids [TDS], conductivity and alkalinity), selected trace elements and dissolved organic carbon [DOC]. In addition, monitoring of suspended solids or sediment is appropriate for evaluation of impacts from surface disturbances.

Based on these analyses, the following set of constituents will be utilized as the basic set of parameters for surface water quality monitoring:

Basic Water Quality (BWQ)

1. <u>General water quality measures</u>
    - total dissolved solids
    - specific conductance
    - pH
    - alkalinity

2. <u>Major inorganics</u>
    - calcium
    - magnesium

potassium
sodium
bicarbonate
carbonate
chloride
nitrate
sulfate
fluoride
ammonia
phosphate
boron
silica (SiO_2)

3. <u>Dissolved organic carbon</u>

4. <u>Trace elements</u>
arsenic
selenium
vanadium
molybdenum
mercury

5. <u>Suspended solids</u>

6. <u>Temperature</u>

7. <u>Discharge rate or water level</u>

Selection of these constituents is supported by the nature of the anticipated sources of water quality impact. In addition, factor analysis of baseline data have shown that most of the natural variability in water quality is explained by constituents included in this listing (RBOSP 1977).

During baseline studies, an extensive set of trace element constituents was analyzed. These constituents are as follows:

Trace Water Quality (TWQ)

aluminum	iron
barium	lead
beryllium	lithium
bismuth	manganese

bromide
cadmium
chromium
copper
gallium
germanium
nickel
~~silica (SiO_2)~~ pg 108
strontium
titanium
zinc
zirconium

Other constituents included in baseline analyses included chemical oxygen demand (COD), color, cyanide, odor, phenols, gross α and β activity, sulfides and selected pesticides.

Semi-annual or quarterly until effects of MIS or Lurgi are known

The background levels of these additional baseline constituents have already been identified from the existing data base. Hence, annual analysis for these constituents is adequate, with sample collection during the low surface flow period (e.g., October). Concentrations of these trace constituents are expected to be generally greater during this time of year, thus enhancing their detectability.

B. Surface Water Monitoring

1. Monitoring Program Elements

The surface monitoring program includes the following elements:

- surface flows and discharges
- springs and seeps
- impoundments/mine sumps/sediment and runoff control ponds
- alluvial aquifers
- erosion and sedimentation

These elements of the hydrologic system may be affected by surface facilities, surface disturbances, waste disposal and discharges. Impacts of these surface activities are likely to be first detected by monitoring of these elements.

2. Types of Samples and Measurements

Evaluation of both temporal and spatial variability allows one to address the complexities of the hydrologic system of Tract C-a and adjoining areas.

With regard to selection of constituents, this evaluation capability requires the following:

- need to include constituents for which baseline data exist and which account for a significant amount of natural variability

- need to measure parameters which relate to potential impacts

- need to measure a consistent set of parameters at control and potentially affected stations

Analysis of pre-development data and evaluation of potential sources of impact are bases for selection of types of samples to be collected or measurements to be made. Changes or impacts will be identified by comparison with baseline or pre-development data, by comparison with control or unaffected areas, and through the use of indicator constituents.

A variety of surface monitoring methods will be used to collect physical and chemical data:

1. surface flow and discharges
    - continuous monitors for specific conductance, temperature, discharge and suspended sediment concentration at U.S.G.S. gages
    - manual measurement of flow at flumes and weirs
    - grab samples for water chemistry analysis
    - field instrument measurement of pH, specific conductance and temperature (field water quality = FWQ)

2. <u>springs and seeps</u>
   - field instrument measurement of pH, specific conductance, temperature and flow (FWQ)
   - grab samples for water chemistry analysis

3. <u>impoundments/mine sumps/sediment and runoff control ponds</u>
   - field instrument measurement of pH, specific conductance and temperature (FWQ)
   - grab samples for water chemistry analysis

4. <u>alluvial aquifers</u>
   - electric sounder or steel tape to measure water level
   - grab samples (bailed) for water chemistry analysis
   - field instrument measurement of pH, specific conductance and temperature (FWQ)

5. <u>erosion and sedimentation</u>
   - measure cross-section profile
   - suspended sediment loads

The basic set of analyses and trace constituents will be monitored at surface stations during the environmental monitoring program. Dewatering/reinjection/discharge activities will require additional sampling of a different set of constituents to meet permit and operational data needs:

- dewatering wells - flow, water level, water quality pressure

- injection wells - flow, pressure, composite water quality (pH, conductivity, temperature, total suspended solids), analysis of source water

- discharge monitoring (NPDES) - flow, pH, conductivity, temperature, total suspended solids, oil and grease, fluoride, boron and other constituents as specified in the permit stipulations (See also 3 above)

Discharges ~~of~~ from sediment control structures will also be monitored in compliance with NPDES permit stipulations.

3. Sampling Frequencies

Detailed specifications of sample frequency are provided in Section 6.4 along with specific elements of the monitoring program. In general, frequencies are varied according to location relative to development activities and potential sources/causes of impact.

Samples will be collected or measurements made more frequently at locations at or near development activities than at stations further from development activities. Lower frequencies are appropriate at upstream background or control sites and at far downstream sites where baselines have already been established and where impacts are either not anticipated or, should they occur, will not be rapid. Concurrent sampling of surface water sites also needed.

For example, the following type of pattern of sampling frequencies will be used for monitoring of locations at or near development activities:

- daily checks of leakage sensing installations and adjacent piezometers
- weekly checks at nearby downgradient alluvial aquifer wells or surface installations [e.g., flumes] field water quality at same time
- monthly or quarterly sampling at further downgradient alluvial and surface installations
- contingency sampling (triggers)

The cost-effective character of this pattern of sampling is derived by focusing on areas where impacts are most likely to be detectable.

C. Deep Aquifer Monitoring

1. Monitoring Program Elements

The deep aquifer monitoring program includes monitoring of upper and lower bedrock aquifers. Major sources of potential impact on these hydrogeologic systems include MIS retort development (including mining), dewatering/reinjection, and recharge through surface facilities.

2. Types of Samples and Measurements

Monitoring of deep aquifers will include measurements of water levels and collection of samples for water quality measurements:

- water levels measured by electric sounder or steel tape
- field instrument measurements of pH, specific conductance and temperature
- grab samples (bailed) for water chemistry analysis

3. Sampling Frequency

Flow rates and hence potential rates of change in deep aquifer systems are slow relative to surface systems. Thus, monitoring frequencies will be low relative to the surface system monitoring program. For example, the following type of program will be generally employed at near field, potentially affected (Type II) stations:

- weekly - water levels
- monthly - water levels, field measurement of pH, temperature and conductivity
- quarterly - basic water quality analysis
- annually - trace constituent analysis
- contingency sampling

6.2 ANALYTICAL APPROACHES

A. Chemical Analysis

1. Analytical Methods and Detection Limits

Analytical methods to be employed are listed in Table 6-6. Also included in the table are detection limits of the indicated method.

2. Laboratory Quality Control and Quality Assurance

Standard laboratory quality control procedures will be followed for the water quality analysis. Elements of the QC/QA program are as follows:

- Instrument Quality Control - Instruments are checked for accuracy and consistency on a regular schedule. Sample blanks, standards, standard additions and spiked samples are routinely used. Periodic instrument service schedules are maintained.

- Laboratory Supplies and Reagents - Clean water supplies meeting EPA specifications are utilized, as are ACS analytical grade reagents and solvents and Class A volumetric glassware.

- Internal Quality Control - Duplicate samples, spiked samples, internal unknowns, TDS-conductivity and cation-anion balances are routinely utilized to verify precision and accuracy of analysis.

- Sample Tracking - Procedures have been developed to trace samples from sample collection through entry of results into the computer data base.

- Blind reference samples

Table 6-6. Analytical Methods and Limits of Detection

Parameter	Reference	Method No.	Detection Lim
Temperature	2	170.1	0.5° C
pH	2	150.1	0.01 pH uni
Electrical conductivity	2	120.1	10 umhos-cm
Bicarbonate	1	403	5.0 mg/l
Carbonate	1	403	1.0 mg/l
Hydroxide	1	403	0.5 mg/l
Sulfate	2	375.3	5 mg/l
Chloride	2	325.3	0.5 mg/l
Nitrate-N	1	419 B	0.1 mg/l
Ammonia-N	2	350.3	0.1 mg/l
Fluoride	2	340.2	0.1 mg/l
Dissolved solids	2	160.1	10. mg/l
Suspended solids	2	160.2	4. mg/l
Phosphate	2	365.3	0.01 mg/l
Cyanide	1	413.1	0.05 mg/l
Phenols	2	420.1	too high 0.05 mg/l
Odor	2	140.1	N.A. ?
Color	2	110.3	N.A.
Oil & Grease	2	413.1	too high 5 mg/l
Bromide	2	320.1	too high 2 mg/l
COD	2	410	5 mg/l
Total alkalinity	1	403	5 mg/l
Al	2	202.1	? 0.1 mg/l
As	2	206.3	0.01 mg/l
Ba	2	208.1	0.1 mg/l
B	2	212.3	0.1 mg/l
Be	1	304 A	0.01 mg/l
Bi	5	Bi	0.05 mg/l
Ca	2	215.1	0.01 mg/l
Cd	2	213.1	0.01 mg/l
Cr	2	218.1	too high 0.1 mg/l

50 times drinking water standards

Table 6-6. (Continued)

Parameter	Reference	Method No.	Detection Limit
Cu	2	220.1	0.01 mg/l
Fe (Total)	2	236.1	0.01 mg/l
Ga	5	Ga	? 2 mg/l
Ge	5	Ge	4 mg/l
Li	1	312 A	0.1 mg/l
Pb	2	239.1	too high 0.1 mg/l
Mg	2	242.1	0.01 mg/l
Mn	2	243.1	0.01 mg/l
Hg	2	245.1	0.001 mg/l
Mo	2	246.1	0.1 mg/l
Ni	2	249.1	0.05 mg/l
K	2	258.1	0.01 mg/l
Se	2	270.3	0.01 mg/l
Sr	1	321 A	0.2 mg/l
Na	2	273.1	0.01 mg/l
Si (SiO_2)	1	301 A	4 mg/l
Ti	5	Ti	1 mg/l
V	2	286.1	0.2 mg/l
Zn	2	289.1	0.005 mg/l
Zr	5	Zr	10 mg/l
Gross Alpha		Proportional counter	
Gross Beta		Proportional counter	
DOC	TOC Analyzer	Leco Method	

REFERENCE NO.

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2 "Methods for Chemical Analysis of Water and Wastes," March, 1979 by Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency. (Publication EPA 600/4-79-020)

3 "1979 Annual Book of ASTM Standards, Part 31, Water", 1979 by the American Society for Testing and Materials.

4 "Microbiological Methods for Monitoring the Environment - Water and Wastes", December 1978 by the U.S. Environmental Protection Agency. (Publication EPA-600/8-78-017)

5 Perkin-Elmer Analytical Methods for Atomic Absorbtion Spectrophotometry, 1979 edition.

B. Experimental Design/Data Base Analysis

1. General Analysis Program

The existing hydrology data base includes measurement of the major chemical and physical hydrologic features of Tract C-a and the surrounding area. These data will be further analyzed to assist in the final design of the hydrology monitoring program. Analyses to be conducted include the following:

- Statistical analysis of spatial variability to verify groupings (or classification) of monitor stations, such as those defined in Section 6.3 of the Scope of Work.

- Statistical analysis of temporal variability to examine importance of seasonal cycles and year-to-year changes over the period of previous monitoring. These results relate to selection of sampling frequencies to monitor seasonal cycles and comparison of current monitoring data with past measurements.

- Uniform description (including statistical descriptions and graphical presentations) of the existing data base to allow effective comparison with current monitoring data.

Data from baseline stations (which will now be classified as Types I, II or III) will form the basis for these analyses.

Statistical analysis plans related to monitoring design include multi-variate analysis of variance (MANOVA) and multiple range tests, cluster analysis and principal components analysis where appropriate. MANOVA will be developed using baseline data and possibly data collected since the baseline period. This analysis procedure provides a multiple evaluation of changes (variability) in time as well as an assessment of various groupings of data.

Water quality data analyses will generally be conducted on:

- temporal groupings of data (e.g., 1975, 1976, 1977, etc. or combinations of these)

- stations (e.g., individual stations or groups)

These evaluations may be presented as analysis of null hypotheses as follows:

H_0: There is no significant difference between years (or times of year)

H_0: There is no significant difference between control (Type I) stations and treatment (Type II or III) station groupings

Dependent variables include chemical constituents by station or time groupings included in baseline and MDP monitoring.

The output from these analyses yields:

- analysis of variability with regard to time (monitoring year), location (sample station) and the interaction of time and location

- statistical summaries of treatment groups

- partial correlations between chemical constituents

- multiple range tests, useful for verification of station groupings when statistically significant interaction and main effects are observed.

As a further evaluation of station groupings, clustering and principle components analysis will be included in this monitoring design program to provide information regarding the station groupings that have smiliar attributes. This information will be used in support of multiple range test information. These analyses may be repeated periodically should significant changes or potential impacts be observed from the routine data evaluation and reporting program.

This design analysis program not only provides tools for finalizing the sampling program but also provides the basis for subsequent review and analysis of hydrology monitoring data. The quality assurance program will also be supported by the results of this analysis (see Section 6.5).

The annual reports will include the following analysis/evaluation program:

1. Descriptive statistics (minimum, maximum, mean where appropriate) will be computed for the report period for each group of monitoring stations to:

   Compare like flow regimes

   - Compare baseline (or other past periods) with report period data. Baseline descriptive statistics, including standard deviation and confidence intervals, will be utilized for these comparisons.

   - Compare control versus potentially affected stations both for the report period and for the baseline period.

   These comparisons, via tabular listings, will be made for each constituent in the monitoring program.

2. MANOVA will be employed to provide the following for the constituents included in the basic water quality program:

   - An evaluation of temporal variability hydrographs ? (e.g., baseline or other past period versus report period).

   - An evaluation of spatial variability (e.g., control versus potentially affected areas).

   In addition to these main effect (time, space) evaluations, interaction effects, partial correlation data and, when appropriate, multiple range tests will be examined to provide insight into possible development-related impacts on the hydrologic system.

3. If appreciable changes are observed from the above outlined analyses, then the following additional analyses will be performed:

- Evaluation of raw data time series to identify sources/causes of change.

- MANOVA analysis on all monitoring constituents for which an adequate sample size exists.

- Repeat principle components or cluster analysis on report period data to assist in identification of the "pattern" of the data.

The preliminary experimental design to be used for the various types of monitoring stations is summarized in the following discussions.

2. <u>Stream Stations</u>

U.S.G.S. stations used during the baseline were as follows:

A - Dry Fork near west boundary of Tract C-a (09306237)

B - Corral Gulch near west boundary of Tract C-a (09306235)

C - Box Elder Gulch near west boundary of Tract C-a (09306240)

D - Corral Gulch east of Tract C-a (09306242)

E - Rinky Dink Gulch near east boundary of Tract C-a (09306241)

F - Yellow Creek near White River (09306255)

G - Stake Springs Draw (09306230)

Station A (Dry Fork) is usually dry and hence very little data have been

collected. Station C (Box Elder Gulch) is sporadically dry, exhibiting flow only during the spring. Station E (Rinky Dink Gulch) is also frequently dry; little water quality data have been collected. Stakes Springs Draw is usually dry and has been ~~eliminated~~ discontinued from the monitoring program. Discontinued because there is no current development related activity.

A possible spatial grouping of baseline stations is as follows:

- Upstream stations - A, B, C (Type I, control or unaffected stations)
- Downstream - D (Type II, potentially affected station)
- E
- F

The Stakes Springs Draw station was considered to be unaffected by development and was deleted from the MDP monitoring program. The water quality observed at Station F (Yellow Creek) is unique and unrelated to stations in close proximity to Tract C-a activities. Station F was retained in the MDP program because it is downstream but it must be placed in a separate group.

Rationale for these groupings is related to:

- topographic location
- similarity in drainage area size
- general upstream-downstream grouping around main development area.

A grouping of Stations D and E was considered. However, they exhibit very different water quality. Rinky Dink (E) flows are all snowmelt - runoff with little or no groundwater contribution from springs. Increased spring discharges as a response to reinjection operations may affect flows at Station E, however.

In the FEBR, Corral Gulch (east and west) and Box Elder Gulch stations were lumped for factor analysis. This was based on the general assumption that

Need station at mouth of Box Elder

they were part of the same hydrologic system. This assumption is generally supported by water quality data. It is advantageous, however, to separate east and west areas for monitoring purposes because of the location of development activities.

Data for Stations B, C, D and F will be utilized for the evaluation of temporal (seasonal) variability. Examination of Figures 2.49, 2.59 and 2.61 in the FEBR indicates that May to August and September to April may be reasonable temporal (seasonal) groupings of stream stations (and also alluvial aquifer wells). MANOVA will be utilized to evaluate temporal changes in water quality data for the following treatment groups (for grouped stations):

- May to August, and September to April

- January and February, March and April, May and June, July and August, September and October and November and December

This analysis will be performed for the baseline data period (~ 1975 -1976) and for the period of post-baseline through 1979.

In addition, continuous data (temperature, conductivity, suspended sediment and flow) will be analyzed using monthly groupings of data for Stations B, C, D and F.

Although the precise station groupings may be changed after completion of the preceding analyses, the likely experimental design and analysis plan for future reporting is outlined below:

1. Temporal comparisons using analysis of variance:

    - Upstream stations, temporal comparison: Baseline stations A, B and C versus MDP stations A, B and C (report period). These may be lumped data for the year or seasonal comparisons based on temporal analysis results.

In addition to U.S.G.S. stream stations, a series of weirs, flumes and culverts have been used in the past on Tract C-a to monitor flows specifically associated with discharges (e.g., dewatering) and other development activities. Stream (surface discharge) stationsto be utilized in the hydrology monitoring program are illustrated in Figure 6-1 and listed in Table 6-7.

Most of these stations are located to monitor surface discharge of dewatering flows which is now an infrequent occurrence. These stations were established in 1979. Their association with development activities generally precludes their use in the baseline reanalysis program.

3. Springs and Seeps

What parameters are measured at the springs and seeps?

In the FEBR (RBOSP 1977), three methods were used to evaluate the source of springs and seeps: 1) location evaluation, relative to potentiometric surface, 2) statistical analysis of flow velocity and 3) correlation of flows from one spring to another. The conclusions were as follows:

- Flow at stations 1 and 2 is alluvial in origin although station 2 may be influenced by upper aquifer water.

- Flow at stations 3, 4, 5 and 8 is from upper aquifer water or recharge water entering the upper aquifer.

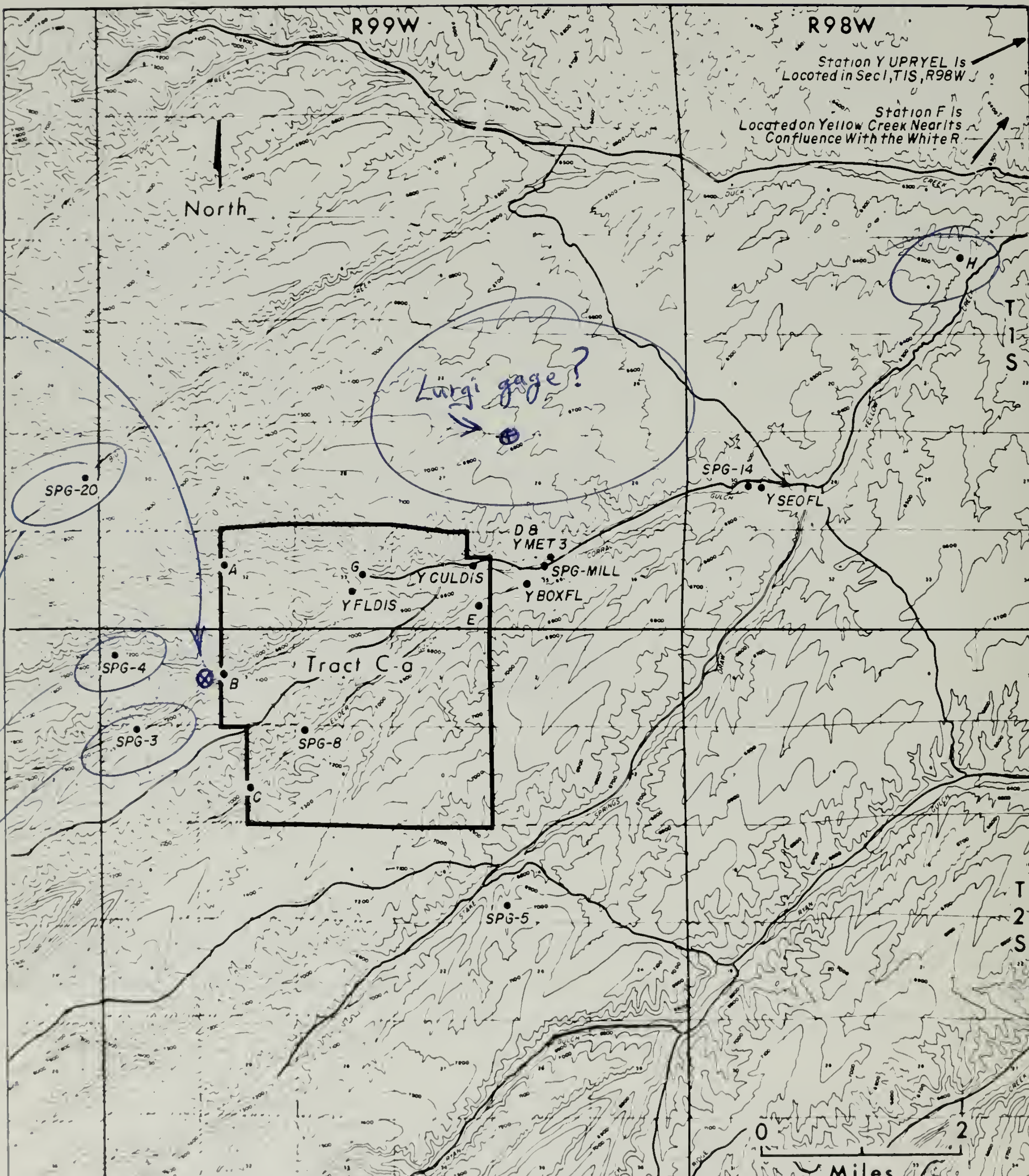
Station 14, which is now monitored, was not sampled until 1977.

From 18 to 24 samples for chemical analyses were collected during the baseline period. In addition, a spring in Corral Gulch (Miller's Spring) is monitored to evaluate the effects of the dewatering/reinjection program.

Stations 1 and 2 exhibit water of alluvial origin predominately, and are in a location completely unaffected by development on Tract C-a. Their only value for flow and water quality monitoring may be as an independent measure of natural spatial and temporal variability in the Basin.

Lurgi site stations (per USGS/BLM/WRD field meetings) ?

Spring at Water Gulch/Corral Gulch ?



See pg 76

off-tract property

Figure 6-1
Surface Discharge Monitoring Stations

Table 6-7. Stream (Surface Discharge) Monitoring Stations

Station/Label	Physical Description
A - USGS	Dry Fork near west boundary of Tract C-a (U.S.G.S.)
B - USGS	Corral Gulch near west boundary of Tract C-a (U.S.G.S.)
C - USGS	Box Elder Gulch near west boundary of Tract C-a (U.S.G.S.)
D - USGS	Corral Gulch east of Tract C-a (U.S.G.S.)
E - USGS	Rinky Dink Gulch near east boundary of Tract C-a (U.S.G.S.)
F - USGS	Yellow Creek near White River (U.S.G.S. only monitor flow, conductivity, suspended sediment)
G - USGS (New)	Dry Fork near Corral Gulch (new U.S.G.S. station)
~~H - USGS (reactivate)~~	~~84 Gulch near Yellow Creek (reactivate U.S.G.S. station)~~ No
Y MET 3	At U.S.G.S. station D
Y BOXFL	Box Elder Gulch upstream of Corral Gulch (flume)
Y FLDIS	NPDES discharge point 001, flume below water treatment plant
Y CULDIS	NPDES discharge point 002, culvert near visitors center
Y SEOFL	Corral Gulch near 84-Ranch (flume)
Y LDGEDGE	Leading edge location (miles from 24 Road crossing) of discharge flow in Yellow Creek
Y UPRYEL	Yellow Creek below 84-Gulch

(NOTE: Y denotes stations that are set up to monitor operations)

Need station near Lurgi site (pg 125)

The flow at stations 3, 4 and 8 is also not likely to be affected by development since these stations are upgradient from development activities and water quality would be unaffected. There is a greater chance of affecting flows at station 5 since it is located at the edge of the cone of depression and new reinjection wells have begun operation relatively nearby. Given the regional direction of groundwater flow to the northwest in this area, water quality would be unaffected by development activities.

Where were these stations?

On the basis of this information, Station 1 will be deleted from the monitoring program. Alluvial well GS-S8 probably provides a better measure of near tract, unaffected alluvial water in this watershed. Station 2 will also be deleted for reasons similar to those given for Station 1. The possible upper aquifer influence can be monitored at springs 3, 4 and 8 in the same general region.

The grouping (to achieve a larger sample size) of Stations 3, 4, 5 and 8 will be tested using MANOVA and cluster analysis with baseline water quality data. The variability between Station 14 and the resultant grouping identified above will be tested with MANOVA techniques and baseline water quality data.

It is not anticipated that spring water quality (particularly as influenced by deep aquifer water) will vary significantly over time. To test this hypothesis, however, and thus to evaluate lumping data over time, the means and variances will be estimated and ANOVA used, for example, for the May to August and September to April groupings proposed for stream stations.

A new spring/seep sampling station will be added to the monitoring program. The new station (SPG-20) is located in the upper reaches of Duck Creek, northwest of the Lurgi Demonstration Project site and north of the open pit. The site is not likely to be directly affected by the operations but flows may be influenced by dewatering around the pit. In addition, a spring near U.S.G.S. gage D (Miller's Spring), been added to the springs and seeps program (SPG-MILL). Stations to be monitored are listed in Table 6-8 and are illustrated in Figure 6-1.

Table 6-8. Spring/Seep Monitoring Stations

Station/Label	Physical Description
SPG-3	Near head region of Corral Gulch
SPG-4	On tributary to Corral Gulch west of Tract C-a
SPG-5	Stake Springs Draw, southeast of Tract C-a
SPG-8	Box Elder Gulch near west boundary of Tract C-a
SPG-14	Corral Gulch east of Tract C-a
SPG-20	Near head region of Duck Creek
SPG-MILL	Separate flow from Corral Gulch near U.S.G.S. - D

4. <u>Impoundments/Mine Sumps/Runoff Control Ponds</u>

Numerous impoundments, mine sumps and runoff control structures have already been constructed for the MIS modular development program. Additional facilities will be constructed with development of the open pit mine and the Lurgi Demonstration Project. Monitoring of these facilities will include source monitoring (of ponds, sump discharges, etc.) and leachate control installation monitoring (of collection systems, adjacent piezometers, etc.). Sampling stations to be included in this portion of the hydrology monitoring program are identified in Table 6-9.

Table 6-9. Source and Leachate Control Installation Monitoring Stations

Station Label	Physical Description
YER Pond	MIS East retention pond
YWR Pond	MIS West retention pond
YERO Pond	MIS East runoff pond
YWRO Pond	MIS west runoff pond
YJEF Pond	East shaft settling pond
YSW - 1 through 7	Sour water ponds
Y LEACH - 1	Leachate collection system - sour water ponds
YPZR - 1 through 4	Piezometers adjacent to sour water ponds
MISUMP	MIS Mine sump discharge

Additional source and leachate control installation monitoring programs are being developed for facilities related to the open pit and to the Lurgi Demonstration project and will be included in the scope of work when completed. General areas of concern include:

- <u>Open pit</u>
  - pit sump
  - sediment/runoff control structures

- <u>Lurgi Project</u>
  - sediment/runoff control structures
  - waste water ponds
  - spent shale pile (leachate collection system)

5. Alluvial Aquifers

Baseline data were collected from four alluvial wells (GS-S7, GS-S8, GS-S11 and GS-S12) as part of the environmental sampling program. Four others were drilled but were dry throughout the baseline period. The above wells are located as follows:

GS-S7	West Boundary-Corral Gulch
GS-S8	West Boundary - Box Elder Gulch
GS-S11	(now called GS-S11D) Corral Gulch east of Tract
GS-S12	Stake Springs Draw (these data not included in FEBR analysis and was deleted from MDP monitoring).

Data were also collected at four additional alluvial wells as part of the 84-Mesa studies:

GS-S19	Upper Duck Creek
GS-S22	Tributary to Yellow Creek
GS-S23	Lower Duck Creek
GS-S24	East of tract on Corral Gulch

Other 84-Mesa wells GS-S15 through GS-S18 were dry during the baseline period. The baseline data base includes data from the period March 1975 through Feburary 1977, giving 11 to 14 data points at each data station.

Other stations added to the data base after the baseline period are as follows:

1. GS-S11A, GS-S11AS, GS-S11S (downstream from tract near the tract boundary)
2. GS-S25, GS-S26, GS-S27A (near MIS development area on tract)
3. GS-S28D, GS-S28AD, GS-S29D, GS-S29AD, GS-S30 (at some distance from tract in Yellow Creek drainage; may be influenced by surface discharge.
4. GS-S13, GS-S14 (Rinky Dink Gulch); to provide background
5. Stake Springs Station (windmill); to provide background

Although these cannot be considered baseline data stations, analysis of the data base will be pursued when sufficient sample sizes exist, to evaluate station groupings around specified development activities, to define the monitoring design.

The analysis approach for alluvial well groupings will be similar to that presented for stream stations. Both temporal and spatial analyses will be included as well as tabular and graphical data summarization.

It is desirable to group alluvial hole stations in a manner similar to that proposed for stream stations:

Upstream ~~Upland~~ Area (Type I)	GS-S7
	GS-S8
Downstream Area (Type II)	GS-S24
84-Mesa (Type III)	GS-S19
	GS-S22
	GS-S23

Alluvial monitoring stations to be utilized in the hydrology monitoring program are listed in Table 6-10 and illustrated in Figure 6-2.

In connection with geotechnical and other exploration activities at the proposed open pit and Lurgi processing site, several holes will be drilled in alluvial deposits in these areas. Depending on the location of these holes and the observation of saturated alluvium, selected sites may be converted to alluvial monitoring holes and included in the program.

Table 6-10. Alluvium Monitoring Stations

Station Label		Physical Description
GS-S6	T1S, R99W	Section 32 - Northwest Corner, Dry Fork
GS-S7	T2S, R99W	Section 5 - West Side - Corral Gulch
GS-S8	T2S, R99W	Section 8 - Southwest Corner - Box Elder Gulch
GS-S25	T1S, R99W	Section 33 - Center - Corral Gulch
GS-S26	T1S, R99W	Section 33 - Center - Corral Gulch
GS-S27	T1S, R99W	Section 34 - Northeast Corner - Corral Gulch
GS-S27A	T1S, R99W	Section 34 - Northeast Corner - Corral Gulch
GS-S11	T1S, R99W	Section 25 - 2.0 m. Northeast of Tract
GS-S11A	T1S, R99W	Section 25 - 2.0 m. Northeast of Tract
GS-S15	T1S, R99W	Section 27 - 1.0 m. North of Tract
GS-S16	T1S, R99W	Section 23 - 1.5 m. North of Tract
GS-S17	T1S, R99W	Section 22 - 1.5 m. North of Tract
GS-S18	T1S, R99W	Section 15 - 2.0 m. North of Tract
GS-S22	T1S, R98W	Section 16 - 6.0 m. Northeast of Tract
GS-S23	T1S, R98W	Section 8 - 6.0 m. Northeast of Tract
GS-S24	T1S, R98W	Section 30 - 3.0 m. Northeast of Tract
GS-S28	T1S, R98W	Section 16 - 6.0 m. Northeast of Tract
GS-S28A	T1S, R98W	Section 16 - 6.0 m. Northeast of Tract
GS-S29	T1N, R98W	Approximately 6 miles below Yellow and Duck Creek confluence
GS-S29A	T1N, R98W	Approximately 6 miles below Yellow and Duck Creek confluence
GS-S30	T1N, R98W	Approximately 8 miles below Yellow and Duck Creek confluence
GS-S30A	T1N, R98W	Approximately 8 miles below Yellow and Duck Creek confluence

off-tract property

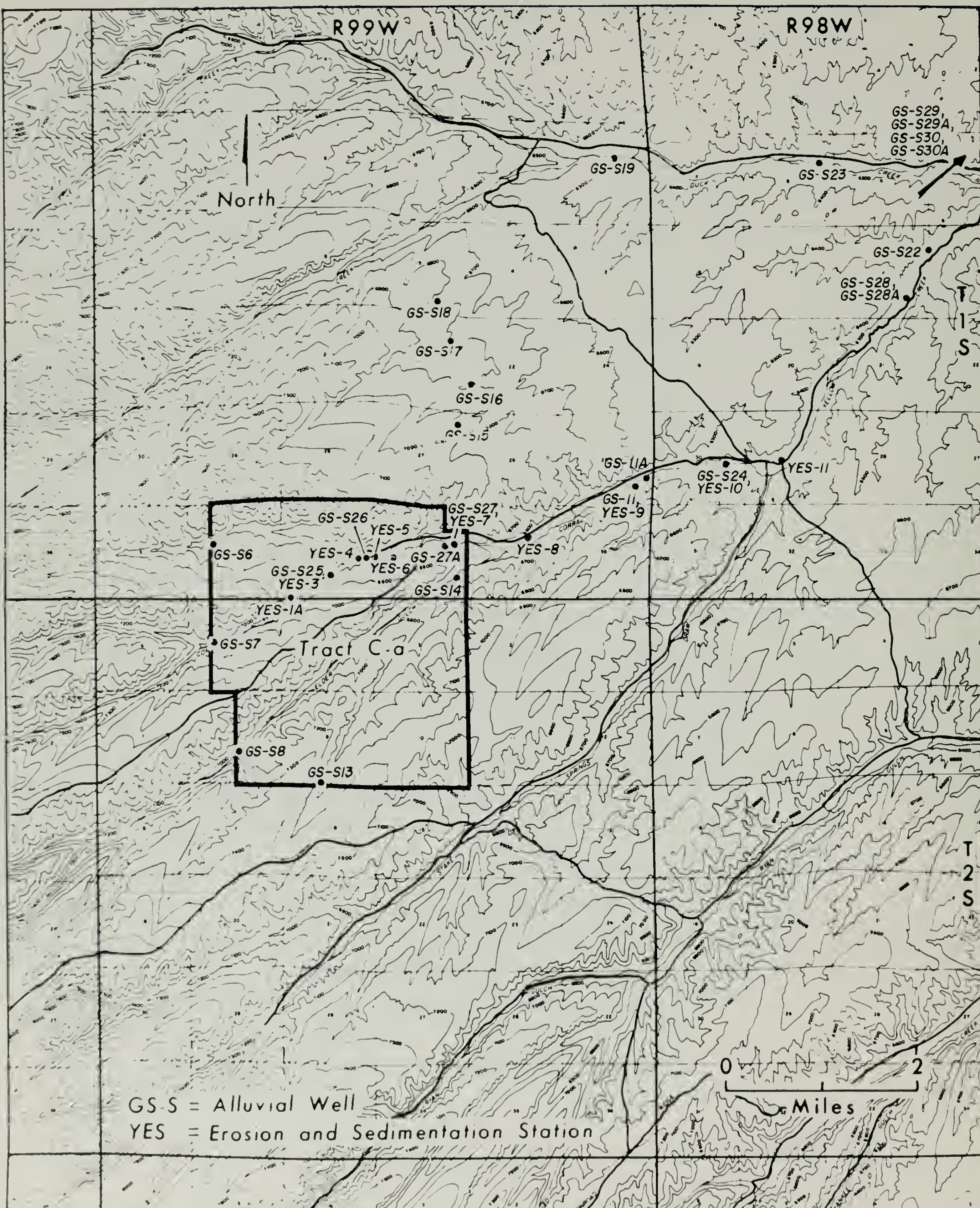


Figure 6-2
Alluvium and Erosion/Sedimentation Monitoring Stations

Sediment characterization ?

6. Erosion and Sedimentation

The erosion and sedimentation monitoring program was established to determine changes in stream channels downstream of pump test and dewatering discharges. The pump test programs have been completed and surface discharges from the dewatering program are now infrequent.

Erosion and sedimentation data are measurements of channel depth across the stream channel. Channel cross-section profiles are developed by taking depth measurements every six inches across the stream channel. Erosion and sedimentation stations included in the hydrology monitoring program are itemized in Table 6-11 and illustrated in Figure 6-2.

Table 6-11. Erosion/Sedimentation Monitoring Sites

Station Label	Physical description
YES-1A	Corral Gulch above GS-S25
YES-3	Corral Gulch at GS-S25
YES-4	Corral Gulch above confluence with Dry Fork
YES-5	Corral Gulch below confluence with Dry Fork
YES-6	Corral Gulch 0.3 miles below confluence with Dry Fork
YES-7	Corral Gulch at GS-S27
YES-8	Corral Gulch at USGS gage D
YES-9	Corral Gulch at GS-S11
YES-10	Corral Gulch at GS-S24
YES-11	Corral Gulch at Highway 24

These data are presented as cross-section plots.

The existing data base will be analyzed to estimate descriptive statistics for each point of the cross section profile. These descriptive statistics will be computed for each "season" as defined from stream data temporal analysis. Future profile data, collected quarterly to provide seasonal data, will be compared to these statistical profile data.

7. Deep Aquifers

Baseline data on the upper and lower aquifers will be analyzed for spatial and temporal variability in a manner similar to that described for stream and alluvial stations. These analytical results will be utilized to verify sample groups (Types I, II and III) described in SOW Section 4.3.

Deep aquifer holes are described in Table 6-12 and illustrated in Figure 6-3. These wells are used for dewatering/reinjection or are included in various aspects of the hydrology monitoring program. Although not a deep aquifer well, YCOINJ (composite reinjection water) is included in Table 6-12.

In addition to these stations, holes into the Uinta Formation and to the A- and B-groove are being drilled around the open pit and Lurgi processing site. Depending on location, saturated zones observed and other data collected during drilling, selected holes may be converted to monitoring wells and included in the hydrology monitoring program.

Define this program as soon as possible.

Table 6-12. Deep Aquifer Stations

Station Label		Physical Description
GS-1U	T1S, R99W	Section 32 - Northwest Corner
GS-2-3U	T1S, R99W	Section 33 - North side - Dry Fork
GS-4-5U	T1S, R99W	Section 34 - Northeast corner - Corral Gulch
GS-6U	T1S, R99W	Section 34 - Northeast Corner - Box Elder Gulch
GS-9U	T2S, R99W	Section 4 - Center - Between Box Elder and Corral Gulch
GS-10U	T2S, R99W	Section 3 - East side
GS-11U	T2S, R99W	Section 9 - South side - Between Rinky Dink and Box Elder Gulch
GS-12U	T2S, R99W	Section 9 - South side - Between Rinky Dink and Box Elder Gulch
GS-13U	T2S, R99W	Section 9 - South side - Between Rinky Dink and Box Elder Gulch
GS-15 U,L	T2S, R99W	Section 10 - Southeast Corner
GS-17L	T1S, R99W	Section 32 - Northwest Corner - Dry Fork
GS-20U	T2S, R99W	Section 10 - Southeast Corner - East of Rinky Dink Gulch
GS-21U	T2S, R99W	Section 10 - Southeast Corner - East of Rinky Dink Gulch
TO-2U	T1S, R99W	Section 32 - Northwest Corner - Dry Fork
TO-3U	T1S, R99W	Section 34 - Northeast Corner - Corral Gulch
CE-701U	T1S, R99W	Section 32 - Northwest Corner - Dry Fork
CE-702U	T1S, R99W	Section 34 - Northeast Corner - Corral Gulch
CE-705AU	T2S, R99W	Section 4 - Center - Box Elder Gulch
CE-707U	T1S, R99W	Section 32 - Northwest Corner - Between Dry Fork and Corral Gulch
CE-708U	T2S, R99W	Section 5 - North of Corral Gulch
CE-709U	T1S, R99W	Section 33 - Near MIS Area
AM-2AU	T2S, R99W	Section 9 - South side
AM-3U	T2S, R99W	Section 8 - Southwest Corner - Box Elder Gulch
GS-M1U	T1S, R99W	Section 29 - 0.5 m. North of Tract

Table 6-12. (Continued)

Station Label		Physical Description
GS-M2U	T1S, R99W	Section 24 - 2.0 m. Northeast of Tract
GS-M3U	T1S, R98W	Section 29 - 3.5 m. Northeast of Tract
GS-M4U	T1S, R99W	Section 21 - 1.5 m. North of Tract
GS-M5U	T1S, R98W	Section 8 - 4.0 m. Northeast of Tract
GS-M6U	T1S, R99W	Section 27 - 0.5 m. North of Tract
GS-M7U	T1S, R99W	Section 30 - 0.5 m. Northwest of Tract
GS-M8U	T1S, R99W	Section 35 - 0.5 m. East of Tract
GS-M9U	T2S, R99W	Section 11 - 0.5 m. East of Tract
GS-M10U	T2S, R99W	Section 14 - 0.5 m. Southeast of Tract
GS-M11U	T2S, R99W	Section 14 - 0.5 m. Southeast of Tract
GS-M12U	T2S, R99W	Section 13 - 2.0 m. Southeast of Tract
GS-D1U	T1S, R99W	Section 33 - MIS Area
GS-D4U	T1S, R99W	Section 33 - MIS Area
GS-D5U	T1S, R99W	Section 33 - MIS Area
GS-D6U	T1S, R99W	Section 33 - Center of Tract - Corral Gulch
GS-D8U	T2S, R99W	Section 3 - East side - Box Elder Gulch
GS-MDP2CU	T1S, R99W	Section 33 - MIS Area
Y COIN J		Composite of reinjection water

off-tract property

# of lower aquifer are inadequate

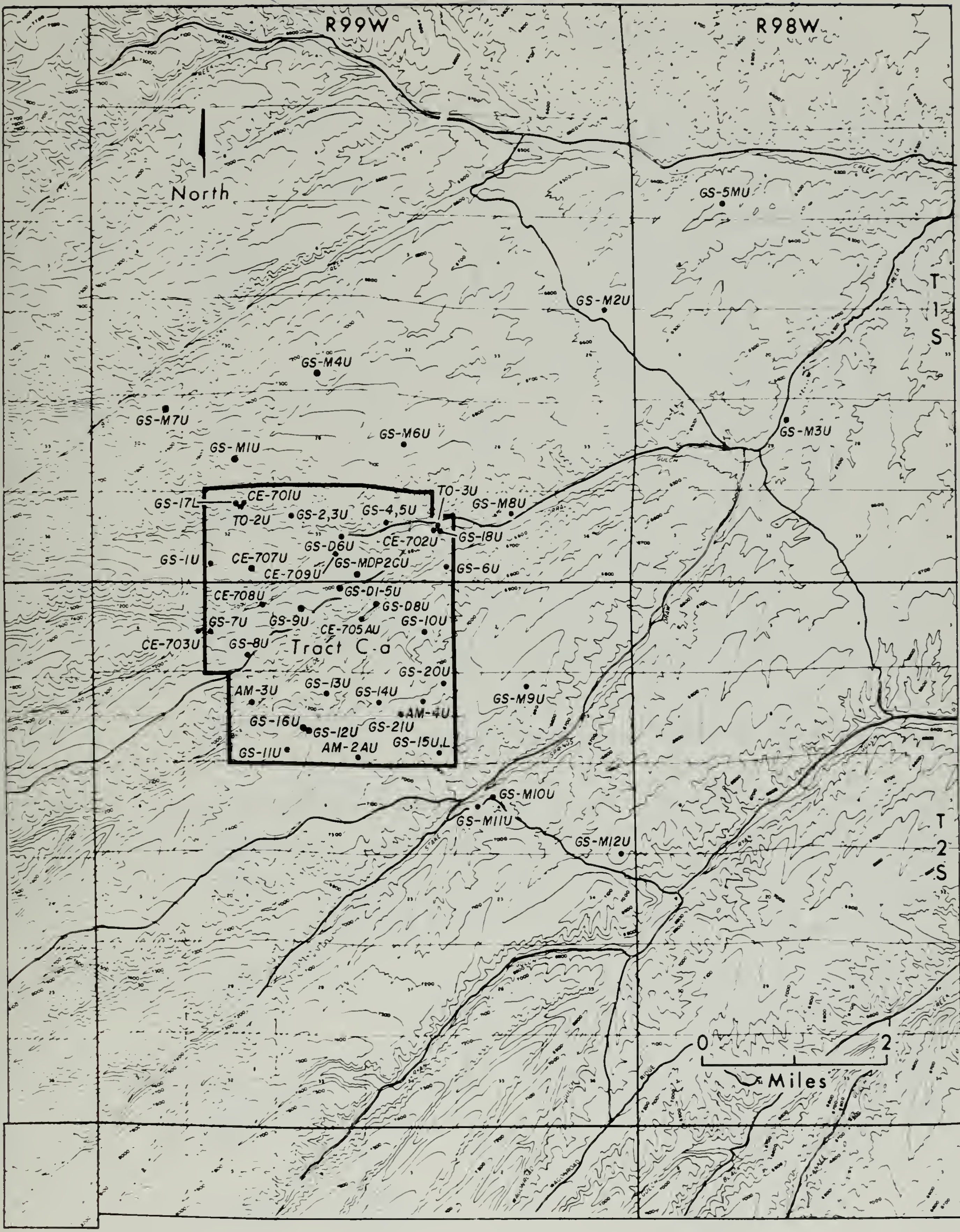


Figure 6-3
Deep Aquifer Monitoring Stations

6.3 SPECIFIC PROGRAM ELEMENTS

Specific monitoring programs for the four major development activities are presented in the following discussions. The orientation with regard to groupings of sample stations and sampling frequencies reflect the basic sampling approach defined in subsection 6.1A (Basic Program Design-Sampling Approach). Basic rationale for the station groupings and sampling frequencies are also provided for:

- Dewatering/Reinjection/Discharge Program
- MIS Modular Development Area
- Open Pit
- Lurgi Demonstration Plant Site

These specific programs represent not only sampling approaches but are also outlines for data analysis and interpretation.

A. Dewatering/Reinjection/Discharge Program

The major effects resulting from this development activity are changes in water levels or flows (when surface releases occur). In addition, general water quality measures (e.g. pH, temperature and specific conductance) are included in this hydrology monitoring program element.

The dewatering program has resulted in a cone of depression in the upper aquifer centered around the MIS development area.

The sampling program for dewatering/reinjection/discharge is summarized in Table 6-13.

Table 6-13. Hydrology Monitoring Program Summary - Dewatering/Reinjection/ Discharge

Station Class.	Monitoring Effect & Station Identification		Sampling Program[1]				
			D	W	M	Q	A
Type I Control	Springs & Seeps					Flow FWQ[2]	
	SPG-3 SPG 4 SPG-5	SPG-8 SPG-MILL					
	Deep Aquifer				WL[3]		BWQ[4] TWQ[5]
	GS-M9U GS-M11U GS-M12U CE-708U	AM-3U GS-9U AM-2U					
Type II Near Field	Active Dewatering Wells		Flow WL Press FWQ	F,B[6]		BWQ	TWQ
	GS-D6U	GS-D8U					
	Mine Seepage		Flow	FWQ		BWQ	TWQ
	MISUMP						
	Active Reinjection Wells		Flow Press FWQ			BWQ	TWQ
	YCOINJ TO-2U GS-4-5U TO-3U	GS-6U GS-20U GS-21U					
	Discharge Sites/Streams		Flow FWQ	F,B			
	YFLDIS						
	Deep Aquifer						
	GS-D5U GS-D1U GS-D4U		WL				
	GS-MDP2CU	CE-702U	WL		FWQ	BWQ	TWQ
Type III Far Field	Streams						
	E-USGS		Continuous monitors, quarterly water quality				
	YLDGEDGE			X[7]			
	Deep Aquifer						
	GS-M2U GS-M3U	GS-M5U				WL	TWQ FWQ BWQ
	GS-10U[8] GS-12U[8]	GS-11U[8] GS-13U[8]		WL			TWQ FWQ BWQ

GS-M10U?

Need lower aquifer wells

Need operational monitoring of the reinjection streams (monthly BWQ quarterly TWQ)

Need lower aquifer wells

Table 6-13. (Continued)

1/ D=Daily, W=Weekly, M=Monthly, Q=Quarterly, A=Annually

2/ FWQ=Field measurements including pH, temperature, conductivity; and for NPDES stations total suspended solids, and oil and grease

3/ WL=Water Level

4/ BWQ=Basic water quality, see text

5/ TWQ=Trace water quality, see text

6/ F=Fluoride; B=Boron

7/ Distance in miles from 84 Road crossing during discharge

8/ Type II WL; Type III Water quality

B. MIS Modular Development Area

The hydrology monitoring program for the MIS development area is summarized in Table 6-14. The station classification scheme of Type I (control, unaffected), Type II (near field, potentially affected) and Type III (far field, potentially affected) is utilized to organize this monitoring activity.

C. Open Pit

The hydrology monitoring program for the proposed open pit area is summarized in Table 6-15. Only Type I (control) and Type II (near field, potentially affected) stations are identified for this program element. Far field stations are potentially affected by both MIS and Lurgi plant activities and thus are not considered acceptable for open pit monitoring.

Is this the plan contained in the DDP?

A mine sump water reinjection program and associated upper aquifer monitoring (to be located to the north and west of the pit) are being designed. Consideration of these will be included in the open pit monitoring program. In addition, holes drilled in the alluvium and into the Uinta and Green River Formations for exploration and geotechnical purposes will be evaluated for use as monitoring sites.

D. Lurgi Demonstration Plant Site

The hydrology monitoring program for the Lurgi plant site is summarized in Table 6-16. Alluvial and deeper holes being drilled for geotechnical and other reasons will be evaluated for possible inclusion in the monitoring program.

These programs need to be finalized as soon as possible. Some of these wells have already been completed for monitoring purposes.

Table 6-14. Hydrology Monitoring Program Summary - MIS Development Area

Station Class.	Monitoring Effect & Station Identification		Sampling Program[1/] D	W	M	Q	A
Type I Control	Streams		Continuous monitors, quarterly water quality				
	B-USGS	C-USGS					
	Springs and Seeps					FWQ[2/] BWQ[4/]	TWQ[3/]
	SPG-3 SPG-4 SPG-5	SPG-8 SPG-14 SPG-MILL					
	Alluvial Aquifer			WL[5/] FWQ		BWQ	TWQ
	GS-S7	GS-S8					
	Deep Aquifer				WL		BWQ TWQ FWQ
	GS-10U GS-15U GS-9U	GS-15L CE-708U	GS-17L ?				
	Erosion & Sedimentation					Channel ~~Profile~~ Cross-section	
	YES-1A	YES-3					
Type II Near Field	Streams		Continuous monitors, quarterly water quality, Plus:				
	D-USGS[6/] YCULDIS YSEOFL	Y MET 3 YBOXFL	Flow FWQ		BWQ		TWQ
	Impoundments		WL Vol In&Out Flow FWQ			BWQ	TWQ
	YER pond YWR Pond YERO Pond	YWRO Pond YJEF Pond YSW 1-7					
	YLEACH-1	YPZR 1-4	CK, FWQ if wet				
	Alluvial Aquifer		WL	FWQ	BWQ		TWQ
	GS-S25 GS-S26	GS-S27 GS-S27A					
	Deep Aquifer			WL	FWQ	BWQ	TWQ
	CE-709U GS-MDP 2CU	CE-702U CE-705AU					
	Erosion & Sedimentation					Channel ~~Profile~~ Cross-section	
	YES-4 YES-5 YES-6	YES-7 YES-8					

Table 6-14. (Continued)

Station Class.	Monitoring Effect & Station Identification		Sampling Program[1] D	W	M	Q	A
Type III Far Field	<u>Streams</u>						
	F-USGS		Continuous USGS gaging station				
	YUPRYEL				Flow	BWQ FWQ	TWQ
	<u>Alluvial Aquifer</u>						
Lower aquifer?	GS-S11 GS-S11A	GS-S24	GS-S28 ? S29 S30		WL FWQ	BWQ	TWQ
	<u>Deep Aquifer</u>						
	GS-M2U GS-M3U	GS-M5U				WL	TWQ FWQ BWQ
	<u>Erosion & Sedimentation</u>						
	YES-9 YES-10	YES-11				Channel ~~Profile~~ Cross-section	

[1]D=Daily, W=Weekly, M=Monthly, Q=Quarterly, A=Annually

[2]FWQ=Field measurements including pH, temperature, conductivity

[3]TWQ=Trace water quality, see text

[4]BWQ=Basic water quality, see text

[5]WL=Water level

[6]Monthly water quality

Table 6-15. Hydrology Monitoring Program Summary - Open Pit Mine Site

Station Class.	Monitoring Effect & Station Identification	Sampling Program[1/] D	W	M	Q	A
Type I Control	<u>Streams</u> A-USGS	Continuous monitors, quarterly water quality				
	<u>Springs & Seeps</u> SPG-3 SPG-4				FWQ[2/] BWQ[4/]	TWQ[3/]
	<u>Alluvial Aquifer</u> GS-S6 GS-S25		WL[5/]	FWQ	BWQ	TWQ
	<u>Deep Aquifer</u> GS-M1U GS-1U GS-M7U CE-707U			WL		FWQ BWQ TWQ
Type II Near Field	<u>Streams</u> G-USGS (New)	Continuous monitors, quarterly water quality				
	<u>Sediment/Runoff Control Structures</u> Overburden Stockpile Topsoil Stockpile Haul Roads	As per NPDES Permit requirements (to be defined by CDOH)				
	<u>Mine Sump</u> Pit Sump Discharge	Flow	FWQ		BWQ	TWQ
	<u>Alluvial Aquifer</u> New Dry Fork Holes (to be defined)		WL FWQ		BWQ	TWQ
	<u>Deep Aquifer</u> CE-701U GS-2-3U GS-17L		WL	FWQ	BWQ	TWQ

Springs & Seeps (SPG-20)

1/ D=Daily, W=Weekly, M=Monthly, Q=Quarterly, A=Annually

2/ FWQ=Field measurements including pH, temperature, conductivity

3/ TWQ=Trace water quality, see text

4/ BWQ=Basic water quality, see text

5/ WL=Water level

Needs to be finalized

Table 6-16. Hydrology Monitoring Program Summary - Lurgi Demonstration Plant Site

Station Class.	Monitoring Effect & Station Identification	Sampling Program[1] D	W	M	Q	A
Type I Control	<u>Springs & Seeps</u>				BWQ[2]	TWQ[3]
	SPG-3 SPG-8 SPG-4 SPG-20					
	<u>Alluvial Aquifer</u>			WL[4] FWQ[5]	BWQ	TWQ
	GS-S24					
	<u>Deep Aquifer</u>			WL		TWQ FWQ BWQ
	GS-M1U GS-M7U GS-M4U					
Type II Near field	<u>Streams</u> establish new site (NE of Lurgi)					
	H-USGS (reactivate)	Continuous monitors, quarterly water quality				
	YUPYEL	Flow FWQ		BWQ		TWQ
	<u>Impoundments</u>	WL Vol In&Out Flow FWQ			BWQ	TWQ
	Runoff ponds Wastewater ponds					
	<u>Alluvial Aquifer</u>					
	GS-S15 GS-S17 GS-S16 GS-S18		WL FWQ	BWQ		
	GS-S22 GS-S23			WL FWQ	BWQ	TWQ
Usable?	<u>Deep Aquifer</u>		WL	FWQ	BWQ	TWQ
	GS-M6U GS-M8U					
Type III Far Field	<u>Streams</u>	Continuous monitors, quarterly water quality				
	F-USGS					
	<u>Alluvial Aquifer</u>			WL	BWQ	TWQ
	GS-S28 GS-S29A			FWQ		
	GS-S28A GS-S30 GS-S29 GS-S30A					
	<u>Deep Aquifer</u>				WL	TWQ FWQ BWQ
	GS-M2U GS-M5U GS-M3U					

Table 6-16. (Continued)

Station Class.	Monitoring Effect & Station Identification	Sampling Program[1/]				
		D	W	M	Q	A

[1/]D=Daily, W=Weekly, M=Monthly, Q=Quarterly, A=Annually

[2/]BWQ=Basic water quality, see text

[3/]TWQ=Trace water quality, see text

[4/]WL=Water level

[5/]FWQ=Field measurements including pH, temperature, conductivity

Impacts from the Lurgi plant operation and waste disposal facilities are best directly monitored at surface facilities and in components of the surface hydrologic system (e.g. alluvium and surface streams). Thus sampling frequencies for these areas are greater than for deep aquifer stations.

6.4 DATA MANAGEMENT AND QUALITY ASSURANCE

A. Field Data

Field measurements (flow, water levels, pH, specific conductance and temperature) are made following procedures described in the RBOSC hydrology field manual. Data are transcribed in the field on sheets formatted for computer data entry. These data are checked for completeness on a weekly basis by the hydrology program supervisor and transmitted to Denver.

Upon receipt in Denver, field data are keypunched and a QC printout is generated. The printout is reviewed to identify spurious or inconsistent data points. Review comments are documented and data are deleted or corrected as indicated from the verification reviews.

After verification, the hydrology data base is updated and data are stored for subsequent plotting, tabulation and data analysis. Periodic field audits are conducted by AOSO staff to verify the use of documented procedures. Documents confirming these audits are placed in the AOSO file. Internal audits by the RBOSC Quality Assurance Officer are conducted without warning on an irregular basis. Memoranda documenting results of these audits and corrective actions are placed in the RBOSC QA file.

B. Laboratory Chemical Analysis

Water chemistry samples are collected and preserved following standard procedures defined in the RBOSC hydrology field manual. The sampling schedule is as defined in the approved scope of work.

Preserved samples are shipped to the analytical laboratory accompanied by log sheets which are used by the laboratory to verify the completeness of the sample shipment. Internal laboratory quality control and quality assurance procedures are summarized in Section 6.2 of the scope of work.

Laboratory analysis data are transferred using floppy disks. These data are used to update the existing data base and are stored in RBOSC data management system for data processing.

RBOSC cooperates with the ~~A~~OSO and the EPA in analysis of independent splits, performance samples, and blanks to verify the accuracy of the laboratory results.

C. U.S.G.S. Data

Data collected at U.S.G.S. gaging stations include continuous data on flow, temperature, conductivity and suspended solids and grab samples for water chemistry analysis. Approved procedures are used for instrument calibration, data verification and correction. Standard laboratory analysis procedures are followed. Verified data are entered in U.S.G.S. computer system and are provided to Rio Blanco for updating of the existing data base and data processing.

D. Data Processing

Data analysis approaches are described elsewhere in the hydrology scope of work. Established, documented catalog procedures (e.g., SAS, SPSS) are used for statistical analysis. Results of data anlyses are reported in year-end reports. These reports are reviewed by the ~~A~~OSO staff and the OSEAP members.

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7.0 SPECIAL MONITORING STUDIES

7.1 TOXICOLOGY

A. Introduction

If a commercial scale oil shale operation is to be developed in this country, attention must be given to the potential hazard of oil shale-related products and by-products to health and the environment. A number of toxicology studies have been or are being conducted and additional research is proposed to assess the potential hazard of oil shale-related emissions, effluents, solid wastes, products and combustion products.

Historic data on workers in the Scottish and Russian oil shale industries indicate that the principal health hazard associated with this industry has been cancer of the skin associated with direct and prolonged contact with shale oil (Weaver and Gibson 1979). These studies, however, cannot be directly related to the oil shale industry in the United States because of vast differences in personal hygiene and mine safety precautions which are practices here. Some scientific studies on the hazard of oil shale (Cox 1980) list fibrotic lung disease from exposure to siliceous dust, poisonous gases in the mine, cancer-causing compounds in shale retorts, and toxic substances in the processing operations as potential hazards of the developing oil shale industry. These hazards are typical of many mining operations, and a number of precautions are routinely taken to lessen such exposures. However, RBOSC is deeply concerned about these potential problems and is actively supporting research to assess and ameliorate these hazards.

The American Petroleum Institute (API) in 1976 initiated a program to investigate selected toxicological properties of raw and spent shale and raw shale oil. This study included evaluating the acute toxicity, chronic inhalation toxicity, carcinogenesis, mutagenesis and teratogenesis, of raw shale shale oil and spent shale. Samples for these tests were collected from oil shale properties throughout the Colorado Plateau and included samples of raw shale from Tract C-a.

A Department of Energy (DOE) sponsored toxicology program was initiated in 1980 to collect more detailed, site-specific toxicology data at Tract C-a on raw oil shale and the products and by-products generated by the MIS processing of this shale. These studies are presently underway and will include the following:

- Detailed chemical and physical characterization of the source materials, process streams, products and by-products

- Evaluation of potential health effects associated with MIS processing of oil shale

- Biological testing of the compounds and materials associated with the MIS extraction procedure

In addition to these aforementioned studies, RBOSC is proposing to conduct supplemental toxicological tests on Lurgi materials to obtain data on the health hazards of these shale products and by-products. RBOSC will also encourage additional work by the DOE and API.

B. Objectives

The objectives of the DOE sponsored research and the proposed RBOSC toxicology studies are as follows:

- Characterize the chemical and physical properties of the raw shale, and the products and by-products from the retorting processes to determine the potential hazard of these materials

- Determine the biological activity (carcinogenicity, mutagenicity, teratogenicity, and toxicity) of oil shale products and by-products to assess the potential worker exposures and environmental hazard.

- Develop an industrial hygiene program, control procedures and technology to mitigate or prevent worker exposure and environmental hazard

C. Methods

1. API Program

RBOSC's parent companies worked closely with the API toxicology task force to define the oil shale research needs and to supply the materials needed for testing. The test materials and procedures selected for this research program are shown in Table 7-1.

The toxicity program included the following elements: acute oral LD_{50} in rats, acute dermal LD_{50} in rabbits, skin and eye irritation in rabbits, skin sensitization in guinea pigs, and chronic inhalation toxicity tests. The carcinogenicity test procedure involved lifetime observations on mice subjected to skin painting of crude shale oils, oil shale and retorted shale solids. Evaluation of mutagenic activity was based upon microbial tests, mouse lymphoma assays and cytogenetic analyses in bone marrow of the rat. In the teratogenicity evaluation, pregnant rats were exposed to graded airborne concentrations of the test materials to determine if developmental anomalies resulted. Analytical testing, such as determining the free silica content and particle size distribution to access potential inhalation exposure, was also conducted to characterize the shale materials. The results of this program have now been published and can be obtained from the API. RBOSC is currently encouraging the API to institute additional studies on Lurgi materials.

2. DOE Research Program

RBOSC has worked closely with the DOE task force to ensure a successful testing program and has provided, and will continue to provide, additional support and assistance in the following areas:

- Assisting in designing the program

- Expert support in developing appropriate testing protocols

- Supplying representative samples for testing

Table 7-1. API Shale Toxicity Testing Program

Material	Location	Process	Acute	Carcino-genesis	Muta-genesis	Terato-genesis	Analy-tical
Raw Shale	Anvil Points		X	X	X	X	X
Raw Shale	C-a Tract		X	X			X
Raw Shale	White River		X	X			X
Shale Oil	Parachute Creek	Tosco	X	X	X	X	X
Shale Oil	Anvil Points	Paraho	X	X	X	X	X
Shale Oil	Anvil Points	Paraho	X	X			X
Shale Oil	Parachute Creek	Union	X	X	X	X	X
Spent Shale	Parachute Creek	Tosco	X	X			X
Spent Shale	Anvil Points	Paraho	X	X	X	X	X
Spent Shale	Anvil Points	Union	X	X			X
Spent Shale	Parachute Creek	Union SGR	X	X			X

- Providing expert review and commentary on reports

The DOE toxicology studies are designed to characterize the materials produced by the MIS retorting process, evaluate the environmental transport, fate and hazard of these materials, and determine methods of controlling the exposure hazard.

Tests under the DOE program will be conducted on the following MIS materials as they become available:

- raw and retorted shale
- product oil (raw?)
- mine seepage water
- groundwater from perimeter wells
- scrubber blowdown
- leachate (from where?)
- product water (retort water?)
- sludge (from where?)
- raw product gases (where in stream?)
- flared product gases
- fugitive gases and particulates
- site air and ambient air

Need specific source and sample history for each sample

Studies will include testing of laboratory test animals to determine the effects of the following:

- Inhalation of various materials and gaseous effluents,
- Ingestion of various materials
- Long-term chronic exposure.

The ~~proposed~~ DOE sponsored toxicology testing program for Tract C-a is summarized in Table 7-2.

The simpler and more rapid tests will be applied first to determine which materials should be assayed by more extensive and more complicated bioassay systems. Initially, the whole sample, e.g., raw shale or retort water, will be assayed by the bacterial tests, and if positive, by tests using mammalian cell cultures, chemical fractionation will then separate chemical classes, e.g., organic bases or acids. The fractions will be tested again by the bacterial and mammalian cell tests and, if positive, they can be further fractionated and tested by the short-term (acute) whole animal tests.

Additional studies will be conducted as part of the DOE program to evaluate the environmental hazard and fate of MIS materials and the potential hazard associated with occupational exposure. RBOSC will work with the DOE task force to design a similar program for Lurgi materials.

3. RBOSC Program

RBOSC plans to conduct supplemental analytical and biological testing of Lurgi materials, products and by-products.

Analytical and physical testing proposed include determination of the following:

- Particle size, shape, hardness
- Density
- Ash content

Table 7-2. ~~Proposed~~ DOE Toxicology Testing Program for Tract C-a

	In vitro					In vivo				
	Chemical Character-ization	Ames	Chromo-somes	Mammal cells	Cyto-toxicity	Inhal-ation	SCE	Pre-natal	Acute	Skin paint
Liquids:										
Oil	X	X	X	X	X	?*	X	?	X	X
Retort Water	X	X	?	?	X		?	X	X	
Mine Seepage Water	X	X	?	?	X		?	X	X	
Dewatering Water	X	X	?	?	X		?	X	X	
Scrubber Blowdown	X	X	?	?	X		?	X	X	
Leachate	X	X	?	?	X		?	X	X	
Sour Water Tank	X	X	?	?	X		?	?	?	
Solids:										
Particulates	X	X	X	X	X	X	X	X	X	X
Scrubber Sludge	X	X	?	?	?	?	?	?	?	?
Raw Ore	X	?	?	?	?	?	?	?	?	?
Spent Shale	X	?	?	?	?	?	?	?	?	?
Gases:										
Offgas	X	?	?	?	?	?	?	?	?	?

*To be determined after initial testing is completed.

- Extractable organics
- Trace metals
- Cyanide
- Phenols
- Priority pollutants (13 PNA's)
- Corrosivity
- Reactivity
- Ignitability
- Extraction procedure toxicity
- Quantitative mineralogy where applicable

Supplemental biological tests that are being considered include acute toxicity assays of materials inhaled, administered orally or applied to the skin, tests of mutagenic and carcinogenic properties, reproductive studies, and evaluation of ocular and dermal irritation and dermal sensitization resulting from exposure to various oil shale-related materials. The toxicological tests, test organisms or tissue cultures, and test materials proposed to be used in the assays are listed in Table 7-3.

These proposed tests will be conducted in replicate with strict adherence to quality control according to the proposed Good Laboratory Practices and Testing Standard developed by EPA (44 CFR Part 145, 44 CFR Part 91).

D. Results and Discussion

1. API Study

In the inhalation studies, rats and monkeys exposed to either raw or spent

Table 7-3. Proposed Supplemental Toxicology Studies to be Conducted by RBOSC as Appropriate Pending the Actions Taken by DOE and API.

Test	Test Organisms of Tissue	MIS Retort Water	Raw Shale Dust	Lurgi Retort Water	~~Spent Shale~~ Lurgi Processed Shale	Lurgi Light Shale Oil	Lurgi Middle Shale Oil	Lurgi Heavy Shale Oil
Salmonella/Mammalian - Microsome Mutagenicity Test	Salmonella bacteria	X	X	X	X	X	X	X
Mouse Lymphoma Forward Mutation Assay	Mouse lymphoma cells	X	X	X	X	X	X	X
Acute Inhalation Toxicity (LC_{50})	Rats					X		
Dermal Teratology Study	Rats and rabbits					X	X	X
Dermal Cytogenetics Study	Rats	X	X	X	X	X	X	X
Unscheduled DNA Synthesis	Rat liver cell cultures	X	X	X	X	X	X	X
Acute Oral Toxicity (LD_{50})	Rats	X	X	X	X	X	X	X
Acute Dermal Toxicity	Rabbits	X	X	X	X	X	X	X
Occular Irritation Test	Rabbits	X		X	X	X	X	X
Dermal Sensitization Study	Guinea pigs	X		X		X	X	X
Primary Skin Irritation	Rabbits	X		X		X	X	X

shale at 10 and 30 mg/m^3 each for 2 years showed no evidence of carcinogenesis or progressive fibrotic lung disease from either material. Dermal application of raw and spent shales resulted in no evidence of carcinogenicity when applied on mice at a dosage of 50 mg twice weekly for a lifetime (approximately 2 years). Similar tests using raw shale oil showed, however, that the raw oil was highly carcinogenic. Tests using refined and semi-refined products were initiated in August 1979. Results of these tests are not available presently but it is anticipated that the refining steps will significantly reduce the carcinogenic and toxic properties of the retort oil (Weaver and Gibson 1979).

Tests of raw and spent shale and crude shale oil to determine teratogenic effects on pregnant rats showed no deformities, although some fetal toxicity was seen in rats exposed to the higher dosages of crude retort oil tested.

All of the raw shale oil samples yielded positive results for mutagenicity in the bacterial assays (Ames test), were either weakly positive or negative for mutagenicity in the mouse lymphoma assay, and showed no mutagenic tendencies in the cytogenetic bioassay.

Results of the studies on acute toxicity, irritation and sensitization are summarized in Table 7-4. Histopathological studies of the test organisms exposed to toxic concentrations of crude shale oils revealed extensive liver damage resulting from both oral and dermal administration of the oil.

2. DOE and RBOSC Sponsored Studies

Although the API study provided valuable data, the only samples from Tract C-a were of raw shale. The DOE sponsored studies and the supplemental RBOSC toxicology investigations will provide more comprehensive and site-specific data for the MIS and Lurgi retorting technologies, but results will not be available in the near future.

Results of these and other toxicology and industrial hygiene studies on oil shale-related substances will be used to develop an industrial hygiene program and control technologies to mitigate or prevent potential health and environmental hazards.

* Provide industrial hygiene program to OSO when developed. Program should include periodic employee health exams, workplace samples and analyses, identification of risk or hazard

Table 7-4. Summary of Results from Acute Studies Conducted by the API

Test	Sample	#	Results
Oral LD50 (Rat)	Crude Shale Oils	(4)	8-10g/kg
Dermal LD50 (Rabbit)	Crude Shale Oils	(4)	5-20mL/kg*
Eye Irritation (Rabbit)	Crude Shale Oils	(4)	Minimal/reversible
	Oil Shales (Ore)	(3)	Negative
	Retorted Shales	(4)	Irrigating/reversible
Dermal Irritation (Rabbit)	Crude Shale Oils	(4)	0.5g/72hrs. Abraided/unabraided
Sensitization (Guinea Pig)	Crude Shale Oils	(4)	
	Oil Shales (Ore)	(3)	Negative
	Retorted Shales	(4)	

*Not firmly established

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7.2 RECLAMATION SUCCESS/EXPERIMENTAL REVEGETATION STUDIES MONITORING

A. Reclamation Success

1. Objectives

Define the size of an area that will be evaluated (> 2 to 5 acre size)

Revegetation of areas disturbed in conjunction with RBOSC activities is accomplished as soon after disturbance ceases as practicable. Seeded areas are monitored in order to ensure that revegetation efforts are resulting in the establishment of a diverse, effective, and long-lasting vegetative cover.

2. Methods

Success of revegetation efforts is monitored along permanently established transects within seeded areas. Transects are placed during the first growing season after planting and are marked at both ends with rebar stakes. Aluminum marking tags identifying the transect number, as well as the beginning and/or end of the transect, are attached to these stakes. Transects are 50 m in length and are oriented such that typical vegetational coverage is sampled. Orientation of transects is perpendicular to the existing slope whenever possible.

Coverage of grasses, forbs, and shrubs is estimated annually within sampling frames (1 m^2) placed at five meter intervals along the transects. Placement of these frames is facilitated by stretching a meter tape between the stakes at either end of the transect. Sampling frames are sub-divided into five percent segments and coverage of individual species is estimated to the nearest one percent. Data are recorded on field data forms, which are formatted for direct computer entry.

Above-ground biomass is determined during the 5th and 10th growing seasons. After coverage estimates have been made, species are clipped at ground level, bagged, oven-dried at 105 C for 24 hours, and weighed using a dial-o-gram balance (± .1 g). In instances where individual species are not identifiable because of grazing or other reasons, plant materials are segregated by growth form for productivity determinations.

Reclaimed highwalls of the open pit will not be revegetated. These walls will consist of bare rock at approximately 1:1 slopes. Monitoring of these slopes via surveyed monuments will be initiated only if similar monitoring of the steeper, operational slopes indicates that unstable areas exist. Should post-mining monitoring be warranted, monitoring locations and frequency will be determined in conjunction with the ~~Area~~ Oil Shale Office and Colorado Mined Land Reclamation Board.

3. Experimental Design and Data Analysis

Reclamation success data are compared to phytosociological data to test the following hypothesis:

> H_0: There is no significant difference between ~~natural and~~ the revegetated areas and predisturbance vegetative types, ~~for a given habitat type~~ based on the percent ground cover ~~coverage~~ of indigenous grass, forb, or shrub species (lumped by growth form).

These hypotheses will be tested using pairwise t-tests.

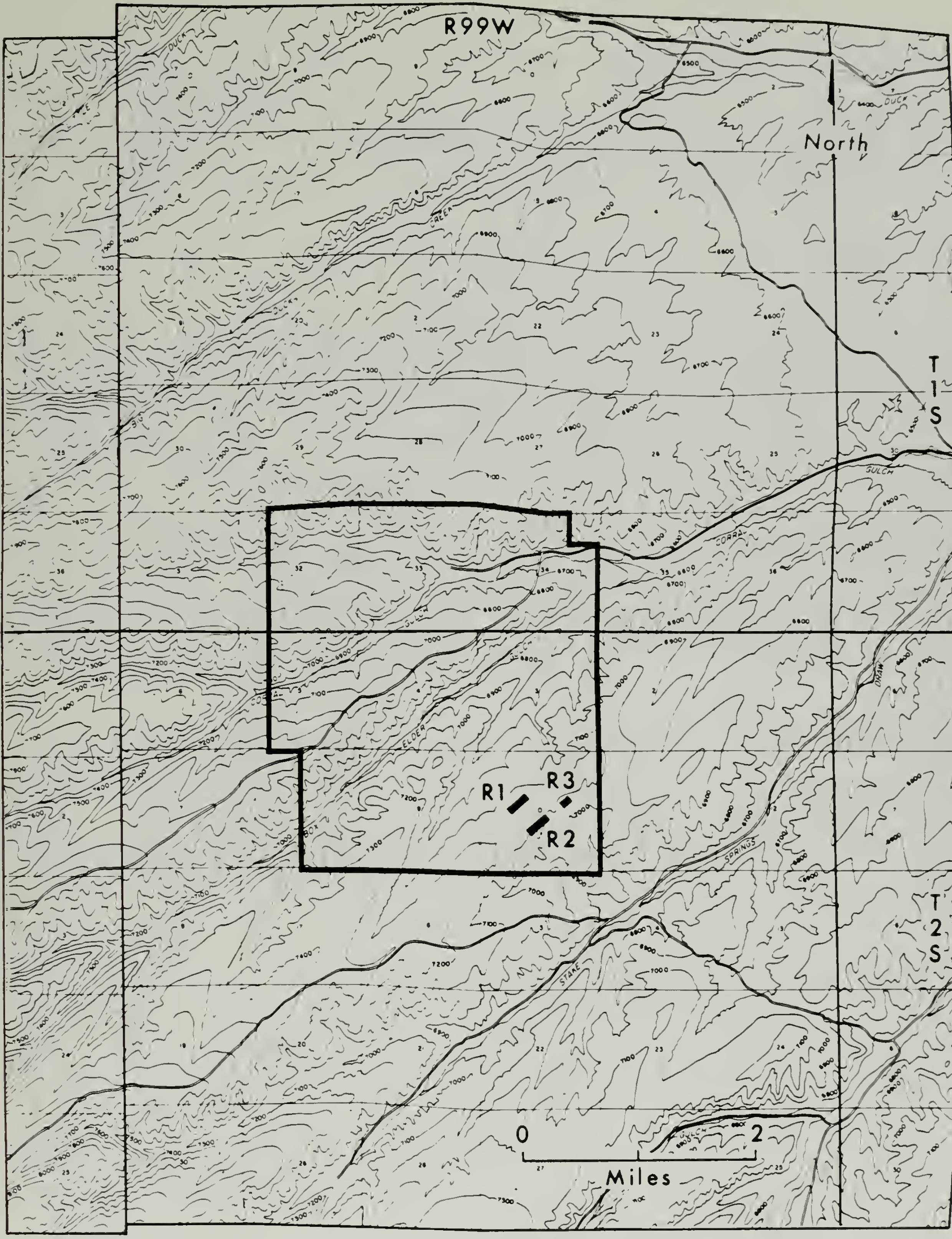
After the 5th and 10th growing seasons, biomass from the revegetated areas is compared with natural range productivity data (unprotected plots) to test the following hypothesis:

> H_0: There is no significant difference between ~~existing range and~~ the revegetated areas and predisturbance vegetative types ~~for a given habitat type~~ based on the productivity ~~biomass~~ of indigenous grass, forb, or shrub species (lumped by growth form).

B. Experimental Revegetation

1. Objectives

Three study sites on Tract C-a are being monitored to investigate experimental revegetation techniques related to surface disturbance and use of an artificial soil profile for revegetation of processed shale (Figure 7-1). Two sites established in 1975 address species adaptability, mulch type, timing of fertilizer



off-tract property

Figure 7-1
Experimental Revegatation Plots

application, and slope aspect variables as they pertain to revegetation of disturbed areas on Tract C-a. The third site, established in 1976, is monitored to assess the effects of seeding rate, mulch type, and establishment of an artificial soil profile on revegetation of Tosco II processed shale.

2. Methods

Coverage of grass, forb, and shrub species is estimated each year on the three experimental revegetation plots. Treatment plots and permanent sampling locations within plots are identified with rebar stakes placed in the upper right hand corners of the plots and/or sampling locations. Aluminum tags attached to these stakes identify the plot number and treatment combination.

Coverage of planted and invaded species is estimated to the nearest one percent within sampling frames (1 m^2) placed adjacent to the permanent marking stakes. Sampling frames are subdivided into five percent divisions to aid in these visual estimates.

Above-ground biomass is monitored on the three sites during the 3rd, 6th, and 10th years of growth. After coverage estimates have been completed, a sampling frame (1 m^2) without divisions is used to delineate the sample area. Individual species are then clipped, bagged, oven-dried at 105 C for 24 hours, and weighed on a dial-o-gram balance (± .1 g).

3. Experimental Design and Data Analysis

Data collected from sites established in 1975 (Plots R_1 and R_2) are used to test the following hypothesis:

H_0: There is no significant difference in cover or biomass for:

1. all 21 species
2. four mulch treatments
3. four fertilizer treatments

Data from plots R_1 and R_2 are analyzed by the following ~~mixed~~ fixed model ANOVA to compare cover and biomass.

	Source of Variation	Degrees of Freedom	F-Ratio
A	Species a=21	a-1= 20	A/~~I~~ H
B	Mulching b=4	b-1= 3	B/~~I~~ H
C	Fertilizer c=4	c-1= 3	C/~~I~~ H
D	A x B	(a-1)(b-1)= 60	D/~~I~~ H
E	A x C	(a-1)(c-1)= 60	E/~~I~~ H
F	B x C	(b-1)(c-1)= 9	F/~~I~~ H
G	A x B x C	(a-1)(b-1)(c-1)= 180	G/~~I~~ H
H	Error (n=3)	abc(n-1)= 672	
	Total	nabc-1=1007	

The study initiated in 1976 (Plot R_3) is designed to test the following hypothesis:

H_o: There is no significant difference in cover or biomass of planted or invaded species based on:

1. soil type
2. seeding level
3. mulch type

Data from Plot R_3 are analyzed by the following ~~mixed~~ fixed model ANOVA to compare cover and/or biomass through time.

Source of Variation	Degrees of Freedom	F-Ratio
~~1.~~ A Soil type a=2	a-1= 1	~~1/8~~ A/H
~~2.~~ B Seeding level b=3	b-1= 2	~~2/8~~ B/H
~~3.~~ C Mulch c=3	c-1= 2	~~3/8~~ C/H
~~4.~~ D Seeding level x Soil type	(a-1)(b-1)= 2	~~4/8~~ D/H
~~5.~~ E Mulch x Soil type	(a-1)(c-1)= 2	~~5/8~~ E/H
~~6.~~ F Mulch x Seeding level	(b-1)(c-1)= 4	~~6/8~~ F/H
~~7.~~ G Mulch x Seeding level x Soil type	(a-1)(b-1)(c-1)= 4	~~7/8~~ G/H
~~8.~~ H Error (n=6)	abc(n=1)= 90	
~~9.~~ Total	abcn-1=107	

7.3 SUBSIDENCE MONITORING (MIS Area)

A. Objectives

Subsidence monuments have been installed and are measured on a periodic basis to determine if any surface displacement occurs due to the dewatering effort, mining and retort preparation the burning of the retorts, or from any other unforeseen cause.

B. Methods

1. Parameters

A survey monument grid was placed on the ground surface over each MDP retort area prior to its rubblization. Additional monuments have been placed in various other areas to determine the effects of dewatering. These monuments consist of a one-inch rebar pin anchored with resin inside a three-inch casing. The coordinates and elevation of each of the monuments have been reported in MDP Monitoring Report 4. RBOSC determined the horizontal and vertical relationship of these monuments to a benchmark sufficiently distant from the retorts to assure that the benchmark does not itself undergo any horizontal or vertical displacement due to MIS activities. Topographic maps at 1" = 200' and a 5-foot contour interval are currently available for the retort area. If substantial subsidence is detected by appreciable movement of the monuments, the topography of the subsided area will be mapped in appropriate detail by plane table or other suitable means. Third order surveying accuracy control will be used for all vertical and horizontal control work.

A check is made on the original subsidence monument survey every six months. Primary vertical control is established at a central point. This point is located fairly close to the site and on the other side of the fault which runs from NW to SE through the area. It is believed that this location is as stable as can be found since subsidence occuring in the retort area would probably not carry through the fault.

A secondary vertical control point has been established at the intersection of the old Airplane Ridge Road and the main access road. The purpose of this point is to reduce the time required for routine checking of the monuments, since it is considerably closer to the site than the primary control point. If subsidence is noted during the routine checks, then a check from primary control will be necessary to insure that secondary control has not settled.

Horizontal control traverses have been run through all the monuments to establish coordinates.

2. Monitoring Locations

The locations and coordinates of thirty-two subsidence monuments placed to-date are shown on the map (see map pocket) dated July 1978.

Additional monuments which will be required above additional retorts and in the general shaft area will be established when appropriate.

3. Monitoring Frequency and Schedule

The horizontal and vertical locations of monument points are established during initial surveys. Subsequent surveys will indicate whether monuments have moved downward and hence whether subsidence has occurred. These will be performed at least every six months. The actual monitoring schedule will be highly dependent on weather conditions, especially in the winter.

Describe sampling frequency as approved by OSO letter 3/21/80

vertical control at 6 month intervals
horizontal control (1/2 of monuments at 6 month intervals)

C. Experimental Design and Data Analysis

During and after the completion of the burn, and during dewatering-reinjection, the position of the monuments of the grid will be monitored in accordance with 2C above. If it becomes apparent that detectable disruption of the surface has taken place, the topography of the surface will be re-mapped to establish the pattern of subsidence. During the burn of the retorts of the MDP, RBOSC will quantify any surface subsidence that may occur. Because of present retort design and what is known of the rocks in the mine area, measurable surface subsidence appears to be highly unlikely.

7.4 RUN-OF-MINE LYSIMETER STUDY

MIS

RBOSC has negotiated with the EPA, USGS and the DOE Task Force to conduct leaching studies on stock-piled run-of-mine ore. As a part of this agreement, RBOSC constructed the leaching apparatus in the stockpile. The cooperating government groups will collect and analyze the leachate.

The collection system consists of three collectors buried beneath the raw shale pile at depths of 5, 10, and 15 feet. Each collector consists of a 10x10 foot square teflon sheeting, contoured so that the percolation is intercepted and conducted to a teflon drain pipe located at the center of the collector. (Figure 7-2). Leachate is then diverted to a series of teflon collection bottles (Figure 7-3) housed in a wooden shelter.

A flow-through electrical resistance probe and a thermocouple has been placed in the teflon collection line to measure conductivity and temperature. Recording rain gages document precipitation quantity in the area of the pile. Snow depths are periodically recorded.

Samples are collected after a precipitation event by the USGS and split for distribution to the involved researchers. Analyses are then analyzed for the constituents indicated on Table 7-5. Results are reported as available by RBOSC in the semi-annual reports.

The lysimeter will be maintained for at least three years. Program was initiated in spring 1980.

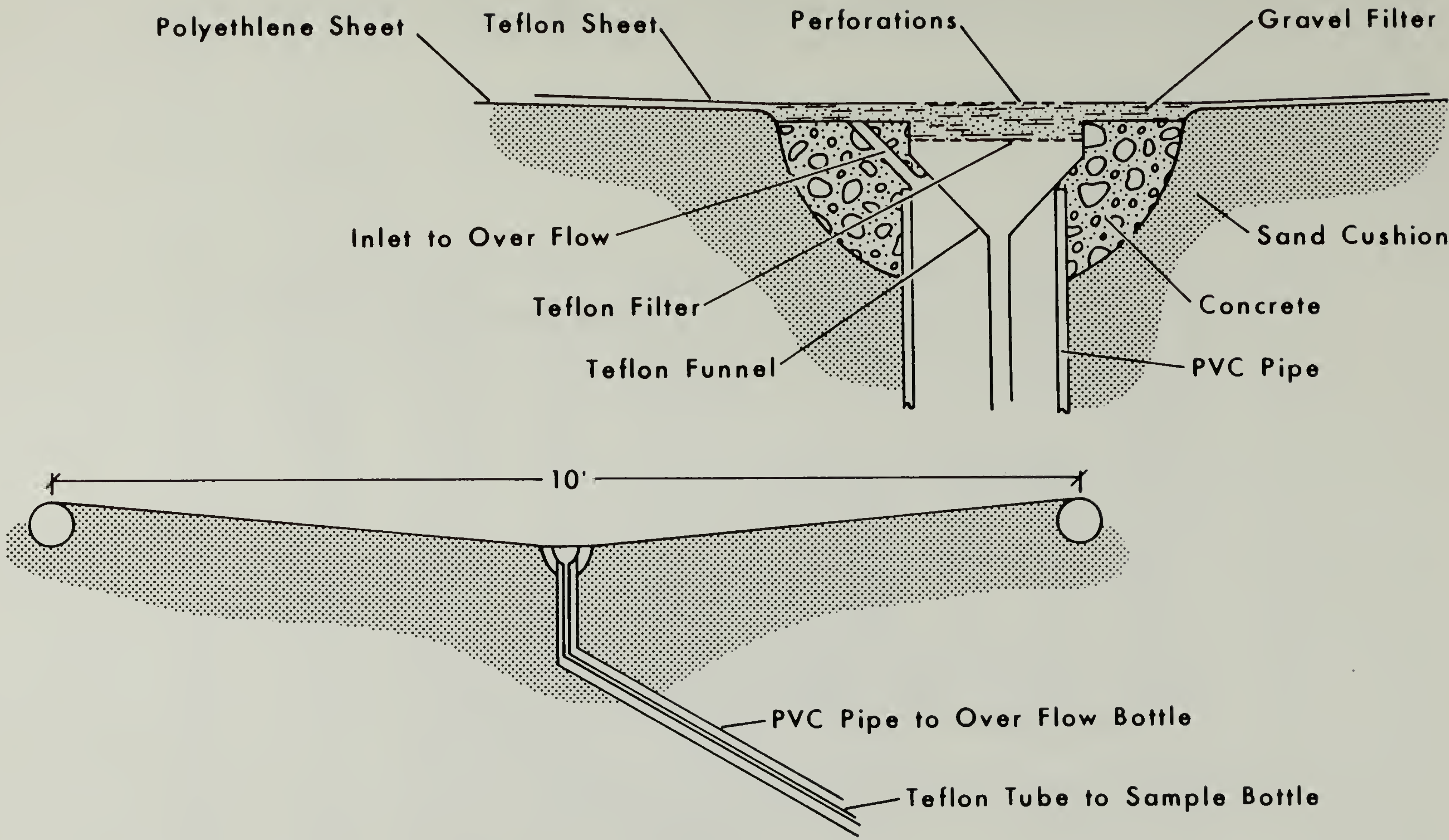


Figure 7-2
Construction Details of the Buried Collectors - Tract C-a

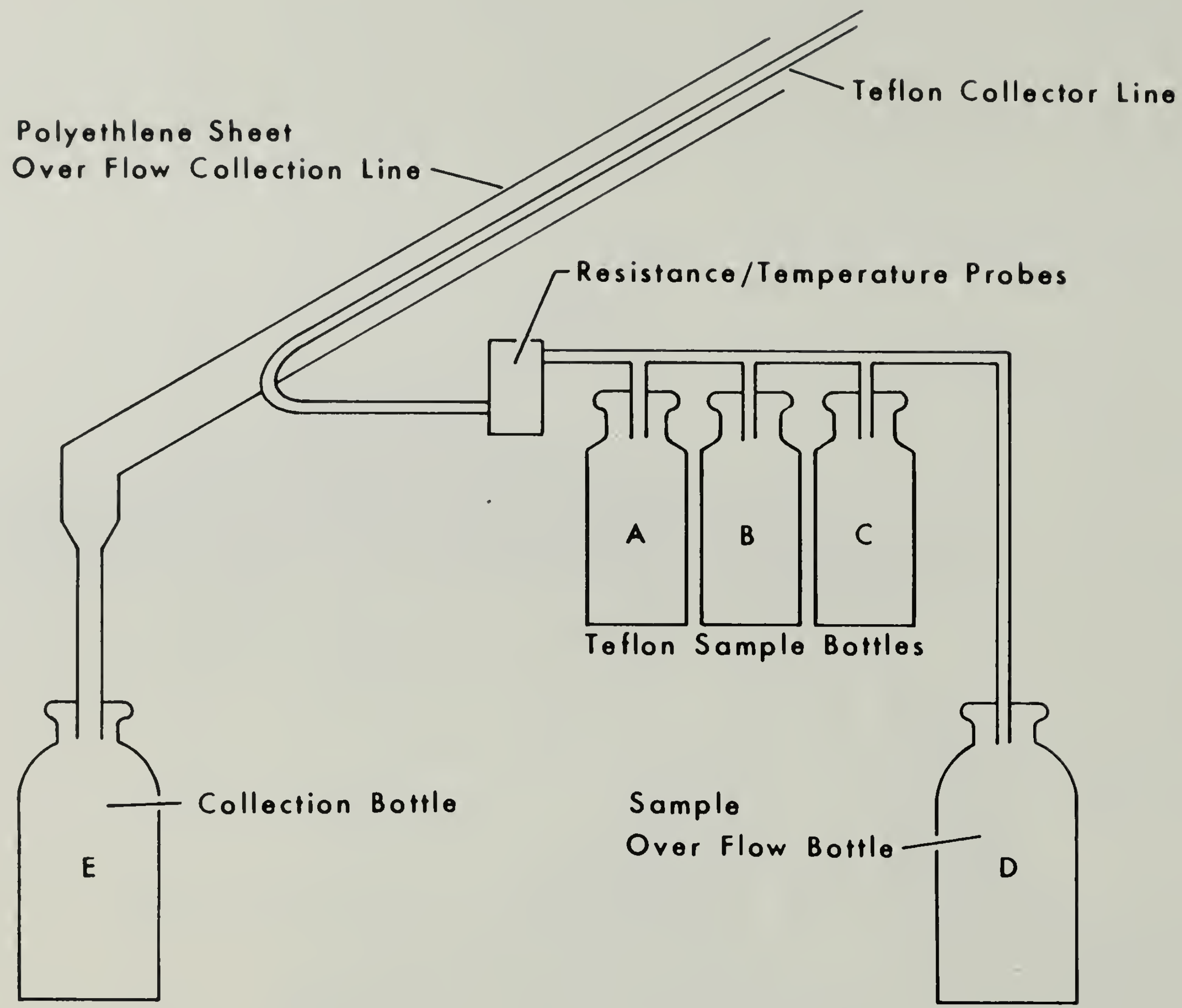


Figure 7-3
Schematic of the Collection Bottle Arrangement

Table 7-5. Raw Shale Lysimeter, Tract C-a Analytical Schedules as of 7/20/80

Investigation - Lab	Constituents to be analyzed
Field	T, EC (electrical conductivity), pH, DO & Total Alkalinity, if sample volume permits.
McWhorter - CSU	Comprehensive list[1/]: Al, Ammonia, As, Asbestos, Ba, Be, HCO_3, B, Cd, Ca, CO_3, Cl, Cr, Co, Cu, CN, F, Fe, Pb, Li, Mg, Mn, Hg, Mo, Ni, No_3, Tot N, PO_4, Tot Phos., K, Se, SiO_2, Ag, Na, Sy, SO_4, Sulfide, Tl, Thiosulfate, Sn, Ti, U, V, Zn, Alk, ec, pH, TDS, DO, T, DOC Fractionation.
	Routine list[2/]: Na, Ca, K, Mg, HCO_3, CO_3, Cl, SO_4, B, F, Al, MO, SiO_2, Thiosulfate, Se, Alk, ec, pH, TDS, DO, T, Zn, DOC Fractionation.
USGS-WRD-~~A~~OSO	Ca, Mg, Na, K, HCO_3, CO_3, NO_3, SO_4, Cl, SiO_2, F, B, Phenols, Tot P, Mn, Fe, As, Ba, Be, Cd, CO, CU,Pb, Li, Mn, Mo, Sr, V, Zn, Ni.
Leenheer - WRD	DOC, DOC Fractionation, selected specific organics.
Wildung - DOE-OSTF	Redox, participate with McWhorter-USGS in replicates, reduced sulfur species (mostly in field).

1/ Initial samples, schedules frequency to be determined as findings progress during the experiment.

2/ Analyses to be run on samples A-D from each lysimeter, unless findings dictate differently.

8.0 ECOLOGICAL INTERRELATIONSHIPS

The RBOSC environmental monitoring program is designed to provide a dynamic assessment of the Tract C-a ecosystem. In order to provide this type of assessment, data analysis techniques within each program will be reviewed and altered as conditions warrant to provide the flexibility necessary to keep the program sensitive to natural and man-induced environmental perturbations, changes in design plans and new found knowledge of the intricacies in the ecosystem. Analyses provided in this section are designed to provide information relative to the interrelationships among data collected in each monitoring program. These analyses will provide the necessary information required to make expert judgements on the interrelationships.

The control/treatment concept of sampling, used in each of the monitoring programs, will serve to identify and separate developmental impacts from natural variability in the ecosystem. Predictive testing and modeling will be applied to appropriate data sets whenever feasible in an attempt to identify future long-term impacts, and recuring sequences of natural phenomena in the ecosystem. The use of sampling sites for collection of data on more than one parameter will allow direct comparisons of driving and state variables. Sampling bias will be avoided to the greatest degree possible and program elements will be altered as necessary to avoid sampling errors. Nonstatistical tests will be employed on low intensity data to supplement quantitative data where necessary.

Three categories exist in which interrelationships for the above sampling programs can be grouped. They are the abiotic-abiotic, abiotic-biotic, and biotic-biotic relationships. The analyses described for each of these categories will satisfy section 1(c)2(d) of the Environmental Stipulations accompanying the Tract C-a Oil Shale Lease, which requires the lessee to "...study, and report to the mining supervisor on ecological interrelationships..."

8.1 ABIOTIC INTERRELATIONSHIPS

The following statement concerning abiotic interrelationships was made in a Tract C-b monitoring report: "Interrelationships among abiotic components and processes in the Tract C-b environmental system are important primarily because the abiotic portion of the system usually functions as a medium for transporting environmental perturbations between the source and the biota of the system. The most important media, of course, are air and water" (C-b Shale Oil Venture 1978). Naturally occuring relationships among abiotic components are not of direct concern in the assessment of the effects of oil shale development. It is important, however, to separate natural events from man-induced changes in order that the nature and extent of development-related impacts may be identified. A large number of abiotic interrelationships were identified for Tract C-a (RBOSP 1977). Some of the more significant of these are identified in Table 8-1.

The climatic factors of Tract C-a (e.g. rainfall events, snowfall, wind patterns, solar insolation) are not likely to be altered by development of Tract C-a. Therefore, changes in related abiotic components (surface water flows, groundwater recharge and availability, etc.) which result from natural climatic variations cannot be attributed to development. The value of studying such relationships lies in being able to recognize natural variations and to distinguish these from man-induced effects.

Abiotic components which are subject to development perturbations include: ambient air quality, ground and surface water quantity and quality, soil erosion potential, slope characteristics and soil chemistry. Changes in ambient air quality can be expected as a result of emissions from stacks, vehicle and generator exhausts and vehicular movement. Introduction of contaminants into the atmosphere can potentially affect the quality of precipitation falling in the region. ~~However, this impact is difficult to monitor because of current limitations in state-of-the-art sampling techniques in lightly industrialized areas. Contamination of samples has been shown to contribute more to the concentrations of constituents in the samples than the air contamination source in such cases. In view of the limited industrial activity in the Tract C-a area in combination with the difficulty of acquiring accurate data on~~

Table 8-1. Important Tract C-a Abiotic Interrelationships

Influence of precipitation on surface water (quality, quantity and velocity)
Influence of atmospheric contamination on the quality of precipitation
Influence of deep aquifer quality on alluvial aquifers
Influence of groundwater quantity on surface water quantity
Influence of groundwater quality on surface water quality
Influence of groundwater flow/movement on surface water quantity and quality
Influence of groundwater level on surface water quantity and quality
Influence of groundwater availability/consumption on surface water availability
Influence of surface water flow on surface water sediment load
Influence of surface water flow on stream bed erosion
Influence of soil erosion on surface water sediment load
Influence of atmospheric contamination on soil chemistry
Influence of slope on drainage basin characteristics
Influence of slope on soil erosion potential
Influence of drainage basin on surface water flow and velocity
Influence of terrain stability on surface water sediment load

pg 43: only soil chemistry to be measured is trace metals and conductivity

precipitation chemistry. RBOSC has chosen not to attempt characterization of precipitation quality on Tract C-a. Data from other studies (including stack sampling) will be used to determine if atmospheric contamination is significant. However, as industrial activity in the area increases, or in case of upset conditions, RBOSC may need to initiate precipitation quality sampling. Information from a variety of sources, e.g. ambient air quality monitors, water quality analyses and vegetation condition and soil chemistry data will be compared with contaminant release data to assess the need for additional sampling and analysis.

Effects on groundwater quality and quantity are anticipated to result from development. Several components of the monitoring program are designed to measure these effects, including water quality of alluvial and deep oil shale aquifers, water levels in various aquifers and drawdown data (see Section 6.0). In addition, modeling results will be used to further characterize these effects. Corresponding changes in surface water flows and quality due to changes in the groundwater regime will be traced through collection and analysis of flow and quality data. A variety of data analysis techniques will be used to identify these relationships, including:

- Discriminant function analysis of chemical differences among the three aquifer systems
- Factor analysis of the chemical constituents in the three aquifer systems
- Time trend analysis of changes in water quality or quantity over time
- Correlation analyses of ground and surface water quality
- Correlation of surface flow with groundwater usage

The soil stratum is another important abiotic environmental component that is likely to be affected by development activities. Potential effects include

soil contamination from atmospheric release, increased erosion, changes in slope aspect and stability and changes in water holding capacity (and runoff). The occurrence of such effects will be tracked by collection and analysis of soils samples (when triggered by contaminant release data), aerial photography, turbidity measurements and sediment and runoff data. Soil sampling and analysis techniques will be evaluated to identify reported interactions of abiotic factors and soil characteristics. Analysis of these relationships will be performed when sufficient sampling bias can be removed from soil sampling techniques and data can be collected in sufficient numbers to provide meaningful examination of the data.

As the physical and water quality data from Tract C-a are evaluated and the interrelationships are more fully understood, data analyses techniques will be re-examined and adjusted as necessary to maximize the utility of the data.

8.2 ABIOTIC-BIOTIC RELATIONSHIPS

The following abiotic-biotic relationships in the Tract C-a area have been determined to be of primary importance (RBOSP 1977):

- Influence of precipitation quantity on vegetation production
- Influence of precipitation quantity on vegetation cover and density
- Influence of precipitation cycles on mule deer densities
- Influence of ambient air temperature cycles on mule deer densities
- Influence of slope/aspect on vegetation cover or composition
- Influence of discharge on vegetation

Aspects of the climatic regime which are of critical importance to plants and wildlife in the Tract C-a area include amount and timing of rainfall and snowfall, length of the growing season, maximum and minimum temperatures and the frequency and velocity of wind (RBOSP 1977). However, RBOSC's activities on Tract C-a and the vicinity are not expected to appreciably affect any of these climatic factors. It is important, though, to be able to determine the influences of natural climatic variations on biotic components of the area and to be able to distinguish natural biotic variability from man-induced variability. Tracking of such interactions will be attempted through the use of analysis of variance, regression, trend analysis and graphical display techniques.

Changes in vegetation identified by study of aerial photographs may trigger additional phytosociological sampling to pinpoint the extent and type of change which has occurred. The source(s) of the change(s) will be investigated by comparison of baseline and monitoring data; review of development activities (e.g. dewatering, releases of air borne pollutants); consideration of wind patterns, climatic factors and regional effects; and comparison of control-treatment areas. Specific data analysis procedures will be designed after more information is available on the nature of the change and in accordance with the resolution of the data available.

Effects of precipitation events on mule deer abundance and distribution in the area may be difficult to assess because of the sporadic nature of area snowstorms and the resulting variation in accumulations of snow in the Tract C-a area. The relationships between these parameters will be established to the greatest extent possible by plotting mule deer pellet plot data on topographic maps and comparing these maps with snow depth data for the tract area. The relationship between mule deer use and vegetation type occurrence will be studied by plotting deer-use isopleths on vegetation distribution maps or photographs. Over time, changes in deer use should be discernible.

The failure of mule deer to utilize a given area will be studied by the following methods:

- Time series plotting of mule deer densities (by seasons) versus time over a period of years
- Cluster plots and analysis of mule deer densities by slope, aspect, vegetation type and elevation by seasons over a period of six years

In the event of discernible major changes in vegetative type distribution, a number of additional studies may be triggered. Among these are the following:

- Soil moisture studies
- Soil chemistry studies
- Analysis of trace metal content in plants from affected and control areas
- Additional small mammal and avifauna studies
- Additional range and browse utilization studies
- Additional deer density studies

Analysis and review of these and other data will aid in identification of the cause of noted changes. As expressed in the C-b developmental monitoring program, however, "Most of the abiotic effects impinging upon the biota of the environment....will be felt through interactions among the biota themselves. For example, disturbed vegetation associated with man's activities in the area will affect the general habitat of plants and animals. It is difficult to say at this time how widespread the effect would be or to what degree specific plants or animals would be affected." Therefore, an analysis of biotic interrelationships is an essential step in attempts to identify "causes" of these changes, as discussed in the following section.

8.3 BIOTIC INTERRELATIONSHIPS

The biotic interrelationships on Tract C-a fall into two distinct ecosystem response units - the aquatic system and the terrestrial system. Interactions between the two systems are limited and difficult to identify or to test. Therefore, the interrelationships to be addressed during the Modular Development Phase will be limited to interactions among terrestrial biota and to those among aquatic biota.

Analysis of baseline data identified important interrelationships between terrestrial biota on Tract C-a and vicinity, including:

- Predator-prey relationships
- Food availability and animal abundance, behavior and distribution
- Cover (habitat) condition in relation to animal survival and population increase or decrease

Environmental data collected during the monitoring program will be evaluated to quantify these relationships, where possible, and to identify the significant components of each interrelationship for the ecosystem of Tract C-a and vicinity. If components can be adequately identified, the monitoring program will be adjusted to provide more meaningful data. Caution must be exercised, however, so that premature and/or incorrect conclusions regarding "cause" for apparent changes in such relationships are not drawn.

Food is the single most important ecosystem component regulating the survival and success of animal populations. In the case of carnivores, the availability of prey determines the presence of absence of the predator. For foraging animals, the condition or productivity of the vegetation is most important.

Unfortunately, predator-prey relationships are particularly difficult to quantify because of the difficulties in determining population status of either the predator or the prey. The coyote census conducted during baseline

studies failed to provide accurate information on populations of this predator in the area. This was also true for other major predators. As a result, quantitative predator-prey studies are not planned for the MDP monitoring program. Qualitative data will, however, be available, including field notes relating to rabbit and coyote sightings in the area, raptor sightings, road kill counts and other similar data. These qualitative data will be used by the Tract C-a field biologist during assessments of development impacts and while preparing reports on the status of the tract environment to complement other, more quantitative data.

Availability of forage will be determined by a number of techniques including aerial photography, analyses of range condition and utilization, analyses of browse condition and utilization, photo plot studies and phytosociological studies. Data from these studies will be compared with forage animal data (e.g. mule deer density, cattle allotments, small animal data) to characterize the terrestrial response units of the ecosystem.

Analyses will include the following:

- Clustering techniques to examine browse type availability and mule deer densities

- Spectral analysis of mule deer densities and browse availability and utilization over time (a minimum of six years data is required for an accurate assessment using this technique)

- Trend analysis of mule deer densities versus browse utilization over time

Although it would be interesting to conduct similar analyses for other animals (e.g. small mammals and birds) RBOSC does not anticipate that available data will be adequate to justify such comparisons.

The data will be evaluated, however, to ascertain suitability for additional analyses. If they are suitable, similar analyses will be completed.

Since vegetation production is closely related to cover, many of the analyses just described will provide insight into the relationship of habitat condition and animal survival and success. These analyses, coupled with surveillence of discrete habitat changes and animal behavior, will help answer questions related to these interrelationships.

The analysis of aquatic ecosystem responses will be directed toward the two most significant components of that ecosystem - the periphyton and benthos communities. Baseline studies have indicated that these two groups significantly impact one another. Periphyton serves as a major source of food for the benthic community and therefore limits and is limited by the benthic component. A series of analyses will be carried out to further define the interrelationship of these two groups:

- Comparison of relative numbers of periphyton and benthos in similar locations over time
- Correlations of species diversities of each group with baseline values
- Time series graphs illustrating the fluctuations in species diversity and relative abundance over time as development proceeds

8.4 SUMMARY

As more data are collected and analyzed, additional insight regarding the function of various components of the ecosystem will be gained. With time, the sampling program and the analyses will be modified to maximize the usefulness of this newly acquired knowledge. RBOSC will not be able to answer all the questions that will be asked about the terrestrial and aquatic ecosystems in the Tract C-a area during the life of this project. RBOSC should be able, however, to add a great deal of information to the existing data base, which will aid researchers, regulatory agencies and industry in the environmentally sound development of the oil shale region.

LITERATURE CITED

C-b Shale Oil Venture. 1978. Development Monitoring Program for Oil Shale Tract C-b. Supplemental Information. Ashland Oil, Inc./Occidental Oil Shale, Inc. Grand Junction, Colorado.

Rio Blanco Oil Shale Project. 1977. Final Environmental Baseline Report. Gulf-Standard. Denver, Colorado.

9.0 QUALITY ASSURANCE, DATA MANAGEMENT, AND REPORTING PROCEDURES

9.1 QUALITY ASSURANCE

The RBOSC Quality Assurance Program is designed to provide documentation that the environmental monitoring program is being conducted in accordance with the approved scope of work and in compliance with standard, approved scientific methods and procedures. In addition, the program must be as thorough and concise as possible, providing organized, accessible quality assurance information. The RBOSC program meets these needs.

The following procedures are the basic components of the RBOSC Quality Assurance Program.

- Use of program-specific field manuals by technicians to assure consistency in sampling

- Regular supervisory checks of all data sheets

- Verification of laboratory results by splits, ion balances, performance samples, and expert review

- Data Management input and subsequent checks

- Review of reports including verification of data in reports

- Periodic internal and external audits of quality assurance files and monitoring program procedures and data

Documentation of the above procedures is contained in a documents file at the RBOSC Environmental Affairs Department office in Denver. Documents retained in this file include monitoring program scopes-of-work, correspondence relating to the monitoring program, summaries of data collection techniques, records of data verification, review of monitoring reports, and results of monitoring program audits.

9.2 DATA MANAGEMENT

The RBOSC Data Management System is an integrated process designed to enable rapid and relatively easy access and retrieval of data collected in the RBOSC Environmental Monitoring Programs. The data management system also functions as a quality assurance component, as data are reviewed and verified several times during the process. The data management system involves four activities: data collection, processing, analysis, and output.

Collection of the data is the most important aspect of the RBOSC data management system. Stringent, documented quality control procedures are implemented on all manual and digital data. This ensures credibility of the data base.

Processing of RBOSC environmental data is a multistep process that varies in complexity and sophistication with each of the monitoring programs. Data are compiled on an appropriate storage medium and then reviewed and edited. All data are sent to Denver and merged into a computerized data base. All data are then reverified and reviewed for accuracy and completeness. by computer or specialist?

Data analysis is performed as specified in the approved Monitoring Program Scope of Work. Evaluation, updating, pooling, and archiving of data are completed as part of this activity. Data analysis also involves testing and implementing new or previously defined analytical techniques. Interpretation of the analyses is also verified. This includes independent review and discussion between qualified scientists in each discipline.

RBOSC reporting requirements are such that the data management system must be flexible enough to generate the output necessary to meet these requirements. Data lists, tables, plots, and analysis output are generated and formatted as needed for the various reports required of RBOSC.

9.3 REPORTING

Mid-year data reports are submitted to the OSO on August 31 (or nearest work day following the 31st) of each monitoring program year. Mid-year reports contain reduced and raw data collected during the specified reporting period and short narrative descriptions of results. Where appropriate, (e.g., Air Studies program) data are placed on magnetic data tapes. One copy of each edited tape is submitted when the mid-year report is submitted. This tape includes data collected during the previous six months.

The year-end data report is submitted to the OSO on March 31st (or nearest work day following the 31st) of each monitoring program year. Year-end reports contain raw and reduced data for the previous reporting period, yearly summaries, analyses and interpretations of the 12-month data set, and, where appropriate, comparisons between years, seasons, and other data sets (e.g., CDOW data). The year-end report is designed to continually update the data base for the tract and vicinity. Trends are identified, anomalies are flagged, and long term evaluations are made. Development-linked perturbations are identified and assessed as to significance. Possible mitigation procedures are recommended.

Reports are entitled "Monitoring Reports" and are numbered sequentially dating from the initiation of the monitoring program in 1977 (Table 9-1). This program will be continued until it becomes necessary to modify it for the commercial phase or it is discontinued by order of the ~~Area Oil Shale Supervisor~~ DCM/OS according to terms of the lease.

Table 9-1. RBOSC MDP Environmental Monitoring Program Report Schedule

Report	Data Collection Period[1/]	Report Submittal Date
Monitoring Report 1	Sept. - Nov. 1977	Feb.28, 1978
Monitoring Report 2	Dec. 1977 - May 1978	Aug. 31, 1978
Monitoring Report 3	June - Nov. 1978	Mar. 31, 1979
Monitoring Report 4	Dec. 1978 - May 1979	Aug. 31, 1979
Monitoring Report 5	June - Nov. 1979	Mar. 31, 1980
Monitoring Report 6	Dec. 1979 - May 1980	Aug. 31, 1980
Monitoring Report 7	June - Nov. 1980	Mar. 31, 1981
Monitoring Report 8	Dec. 1980 - May 1981	Aug. 31, 1981
Monitoring Report 9	June - Nov. 1981	Mar. 31, 1982
Monitoring Report 10	Dec. 1981 - May 1982	Aug. 31, 1982
Monitoring Report 11	June - Nov. 1982	Mar. 31, 1983
Monitoring Report 12	Dec. 1982 - May 1983	Aug. 31, 1983

1/ Data not received during the reporting period will be reported in the report for the period following receipt.

Form 1279—3
(June 1984)

BORROWER'S CARD

Scope of work

DATE LOANED	BORROWER		DATE RETURNED

USDI — BLM

(Continued on reverse)